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Assessing the status of the cod (*Gadus morhua*) stock in NAFO Subdivision 3Ps in 2015

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

The status of the cod stock in the Northwest Atlantic Fisheries Organization (NAFO) Subdivision 3Ps was assessed during a Fisheries and Oceans Canada (DFO) Regional Peer Review Process meeting held October 20-22, 2015. Stock status was updated based upon information collected up to spring 2015. Principal sources of information available for the assessment were: a time series of abundance and biomass indices from Canadian winter/spring research vessel (RV) bottom trawl surveys, inshore sentinel surveys, science logbooks from vessels < 35 ft., logbooks from vessels > 35 ft., reported landings from commercial fisheries, oceanographic data, and tagging studies.

Total landings for the 2014-15 management year (April 1-March 31) were 7,166 t or just 54% of the Total Allowable Catch (TAC), and this marks the sixth consecutive season that the TAC has not been fully taken. The 2015-16 fishery was still in progress at the time of the meeting. The removals through recreational fishing are unknown since 2007, but based on previous estimates are thought to be a small fraction (~ 1%) of the commercial landings.

Estimates of abundance and biomass from the DFO RV spring survey have been relatively stable over the past seven years (except for a high value in 2013 apparently influenced by a year-effect), with abundance being slightly higher than it was in the early 2000s and biomass being generally lower than it was in the early 2000s. The 2015 survey was dominated by young fish which are not yet of commercial size. Sentinel gillnet catch rates have been very low and stable since 1999. Sentinel linetrawl catch rates have been below average for the past six years and the 2014 catch rate was the lowest in the time series. Gillnet catch rates from logbooks of vessels < 35 ft. have been generally stable since 1999 but increasing to slightly above average in 2014. Linetrawl catch-rates decreased over 2006-10, but subsequently increased and are presently at the time-series average.

Estimates of Spawning Stock Biomass (SSB) derived from a survey-based (SURBA) cohort model increased considerably over 2009-12 but have since declined. The 2014 and 2015 estimates are approximately 1.4 times higher than the limit reference point (LRP), and the stock is currently in the 'cautious zone' according to DFO's Precautionary Approach (PA) Framework.. The probability of being below the LRP in 2015 is low (~0.05). Recruitment has improved over the last decade with most cohorts at or above the time-series (1983-2014) average. In particular, indications are that the 2011 and 2012 cohorts are strong. Estimated total mortality has generally been increasing since 1997 to near the time-series maximum. Over 2012-14, it averaged 0.65 (48% annual mortality), which is high especially considering that reported landings have been about half of the TACs over this time period.

Projection of the stock to 2016 was conducted assuming mortality rates will be within ±20% of current values (2012-14 average). Projection scenarios indicate that the 2016 SSB will increase from the 2015 estimate, with median 2016 relative SSB projections ranging from 1.7 to 2.1. In each of the scenarios, the probability of being below the LRP in 2016 is low (≤ 0.05).

Despite short-term projections for stock growth, there is reason for concern for 3Ps cod going forward. Although recruitment has recently been good, mortality is very high and hence the long-term contribution of these year classes to the fishery and spawning biomass is still uncertain. The spawning biomass is composed almost entirely of young fish, with the current age at maturity being the lowest recorded in the time series. Recent biological data suggest fish growth rates are low and that fish condition is poor. In recent years, cod in 3Ps have been feeding heavily on lipid-poor prey such as snow crab and other invertebrates. The combination of these biological data with the recent rise of warm-water species such as white hake is suggestive of broad changes in the 3Ps ecosystem and perhaps reduced cod productivity.

Évaluation de l'état du stock de morue (*Gadus morhua*) de la sous-division 3Ps de l'OPANO en 2015

RÉSUMÉ

L'état du stock de morue de la sous-division 3Ps de l'Organisation des pêches de l'Atlantique Nord-Ouest (OPANO) a fait l'objet d'une évaluation lors d'une réunion du processus régional d'examen par les pairs de Pêches et Océans Canada (MPO) tenue du 20 au 22 octobre 2015. L'état du stock a été mis à jour à partir des données recueillies jusqu'au printemps 2015. Les principales sources d'information disponibles ayant été utilisées pour l'évaluation sont : une série chronologique des indices d'abondance et de biomasse obtenus à partir des relevés au chalut de fond effectués à l'hiver et au printemps par un navire de recherche canadien, des relevés par pêches sentinelles côtières, les journaux de bord scientifiques des navires de moins de 35 pi, les journaux de bord des navires de plus de 35 pi, les débarquements déclarés des pêches commerciales, des données océanographiques et des études de marquage.

Les débarquements de l'année de gestion 2014-2015 (1er avril au 31 mars) se chiffrent à 7 166 tonnes, soit seulement 54 % du total autorisé des captures (TAC). Il s'agit de la sixième saison consécutive où le TAC n'est pas atteint. Au moment de la réunion, la pêche de 2015-2016 était toujours en cours. Depuis 2007, on ne connaît pas les prélèvements de la pêche récréative. Toutefois, les estimations précédentes donnent à penser qu'ils représenteraient une petite fraction (environ 1 %) des débarquements commerciaux.

Les estimations de l'abondance et de la biomasse obtenues à partir des relevés de printemps effectués par le navire de recherche du MPO sont relativement stables depuis les sept dernières années (à l'exception d'une valeur plus élevée en 2013, qui semble avoir été influencée par un effet propre à l'année). L'abondance est légèrement plus élevée qu'au début des années 2000 et la biomasse est, de manière générale, plus faible que durant ces années. Le relevé de 2015 a révélé la prédominance de jeunes poissons n'ayant pas encore atteint la taille commercialisable. Depuis 1999, les taux de prise des pêches sentinelles au filet maillant sont très faibles et stables. Depuis six ans, les taux de prise des pêches sentinelles à la palangre sont inférieurs à la moyenne. L'année 2014 est celle où le taux de prise a été le plus faible. Les taux de prise des pêches au filet maillant tirés des journaux de bord des navires de moins de 35 pieds sont passablement stables depuis 1999, mais ils ont augmenté en 2014, où le taux est légèrement supérieur à la moyenne. Les taux de prise des pêches à la palangre ont diminué au cours de la période 2006-2010, mais ont ensuite augmenté. Ils se situent actuellement dans la moyenne de la série chronologique.

Les estimations de la biomasse du stock reproducteur (BSR) calculées à partir d'un modèle de cohorte basé sur les relevés (SURBA) ont augmenté de façon importante au cours de la période 2009-2012, mais ont connu un déclin depuis. Les estimations de 2014 et 2015 sont environ 1,4 fois plus élevées que le point de référence limite (PRL), et le cadre de l'approche de précaution du MPO indique que le stock se situe actuellement dans la « zone de prudence ». La probabilité que la biomasse se situe sous le PRL en 2015 est faible (environ 0,05). Au cours des dix dernières années, le recrutement a augmenté, la plupart des cohortes se situant dans la moyenne de la série chronologique (1983-2014) ou la dépassant. Entre autres, les indications montrent que les cohortes de 2011 et 2012 sont abondantes. Depuis 1997, la mortalité totale estimée est, de manière générale, en hausse, et elle se situe aujourd'hui près du maximum de la série chronologique. De 2012 à 2014, sa moyenne était de 0,65 (mortalité annuelle de 48 %), ce qui est élevé, compte tenu du fait que les débarquements déclarés comptaient pour environ la moitié du TAC durant cette période.

Les prévisions relatives au stock de 2016 ont été effectuées en supposant que les taux de mortalité varieront d'environ 20 % par rapport aux valeurs actuelles (moyenne de 2012 à 2014). Les scénarios de projection indiquent que la BSR de 2016 sera plus élevée que l'estimation de 2015, les prévisions relatives médianes de la BSR de 2016 se situant entre 1,7 et 2,1. Dans chacun des scénarios, la probabilité que la BSR se situe sous le PRL en 2016 est faible (inférieure ou égale à 0,05).

Malgré les prévisions à court terme, qui laissent présager une croissance du stock, il y a lieu de se préoccuper de la morue de la sous-division 3Ps. En dépit du recrutement adéquat ces dernières années, le taux de mortalité est très élevé. Ainsi, la contribution à long terme de ces classes d'âge pour la pêche et la BSR demeure précaire. La BSR est presque entièrement composée de jeunes poissons, et l'âge de maturité actuel est celui le moins élevé parmi ceux enregistrés dans la série chronologique. Les données biologiques récentes donnent à penser que les taux de croissance du poisson sont faibles et que celui-ci est en mauvais état. Ces dernières années, la morue de la sous-division 3Ps s'est essentiellement alimentée de proies peu riches en lipides telles que le crabe des neiges et d'autres invertébrés. Ces données biologiques, combinées à l'essor récent des espèces d'eau chaude comme la merluche blanche, laissent présager que l'écosystème de la sous-division 3Ps subira des changements importants et que la productivité de la morue pourrait diminuer.

INTRODUCTION

This document gives an account of the 2015 assessment of the Atlantic cod (*Gadus morhua*) stock in North Atlantic Fisheries Organization (NAFO) Subdiv. 3Ps located off the south coast of Newfoundland (Figs. 1 and 2). The history of the cod fishery in NAFO Subdiv. 3Ps and results from other recent assessments of this stock are described in previous documents (e.g. see Brattey et al. 2008; Healey et al. 2013 and references therein). A regional assessment meeting was conducted during October 2015 (DFO 2016) with participation from Fisheries and Oceans Canada (DFO) scientists, a scientist from IFREMER (France), DFO fisheries managers, academia, fishing industry representatives from Canada, and representatives from the province of Newfoundland and Labrador and a non-government organization.

Various sources of information on 3Ps cod were available to update the status of this stock. Commercial landings through September 2015 were available. The results of the 2015 DFO RV survey were reviewed in detail and compared to previous survey results. Additional sources of information included commercial logbooks, inshore sentinel surveys and exploitation rates estimated from cod tagging conducted in 3Ps during 1997-2014. A survey-based assessment model (Cadigan 2010) was used to smooth signals in the RV survey, and provided estimates of biomass, total mortality and recruitment for the stock as covered by the DFO RV survey. Short-term projections of these estimates under total mortality levels similar to current levels were also evaluated to advise on the management of this stock.

The French overseas territory of St. Pierre et Miquelon is within the boundaries of NAFO Subdiv. 3Ps. Following extension of jurisdiction by each country to 200 miles in the late 1970s, only Canada and France have fished in this area. This stock is jointly managed by Canada and France through formal agreements.

ASSESSMENT

TOTAL ALLOWABLE CATCHES AND COMMERCIAL CATCH

Total Allowable Catch

The cod stock in Subdiv. 3Ps was subject to a moratorium on all fishing from August, 1993 to the end of 1996. Excluding these years, the magnitude of the Total Allowable Catch (TAC) has varied considerably over time, ranging from 70,500 t in 1973, the initial year of TAC regulation, to 10,000 t in 1997 (Fig. 3). Beginning in 2000, TACs have been established for seasons beginning April 1 and ending March 31 of the following year (During January-March 2000, an interim TAC was set to facilitate this change). The TAC was set at 11,500 t for five consecutive management years (2009/10-2013/14) and was subsequently increased to 13,225 t for the 2014/15 management year and 13,490 t for the 2015/16 management year. Under the terms of the 1994 Canada France agreement, the Canadian and French shares of the TAC are 84.4% and 15.6%, respectively.

Commercial Catch

Prior to the moratorium, Canadian landings for vessels < 35 ft (see "Can-NL fixed" in Table 1) were estimated mainly from purchase slip records collected and interpreted by Statistics Division, DFO. Shelton et al. (1996) emphasized that these data may be unreliable. Post moratorium landings for Canadian vessels < 35 ft come mainly from a dock side monitoring program initiated in 1997. Landings for Canadian vessels > 35 ft come from logbooks. Non-Canadian landings (only France since 1977) were compiled from national catch statistics

reported by individual countries to NAFO. In recent years, French landings have been provided directly by French government officials.

Cod in the 3Ps management unit were heavily exploited in the 1960s and early 1970s by non-Canadian fleets, mainly from Spain and Portugal, with reported landings peaking at about 87,000 t in 1961 (Fig. 3a). After extension of Canadian jurisdiction in 1977, cod catches averaged between 30,000 t and 40,000 t until the mid-1980s when increased fishing effort by France led to increased total reported landings, with catches increasing to about 59,000 t in 1987. Subsequently, reported catches declined gradually to 36,000 t in 1992. Catches exceeded the TAC throughout the 1980s and into the 1990s. The Canada-France boundary dispute at this time led to fluctuations in the French catch during the late 1980s. Under advice from the Fisheries Resource Conservation Council, a moratorium was imposed on all directed cod fishing in August 1993 after only 15,216 t had been landed. Access by French vessels to Canadian waters was restricted in 19[illegible].

Total landings for the 2014-15 management year (April 1–March 31) were 7,166 t, or 54% of the 13,225 t TAC. This marks the sixth consecutive year in which the landings have been less than the TAC. Over the past four years the landings have averaged half the TAC. Industry participants have indicated multiple reasons contributing to this change, including reduced availability of fish, poor marketing conditions/economics, and the closure of a processing facility in St. Pierre. Prior to the 2009-10 season, the TAC had been fully utilized if not exceeded in each year since Canadian jurisdiction was extended in 1977. Furthermore, excluding the moratorium years, current landings are the lowest of the available time series. Preliminary landings data for 2015 to October 1 totaled 1,554 t. Although the 2015-16 fishing season is incomplete, these totals to date are again relatively low and it is unlikely that the full TAC will be landed.

Since 1997, most of the TAC has been landed by Canadian inshore fixed gear fishermen (where inshore is typically defined as unit areas 3Psa, 3Pfa, and 3Psc; refer to Fig. 1), with remaining catch taken mainly by the mobile gear sector fishing the offshore, i.e., unit areas 3Psd, 3Pse, 3Psf, 3Psg, and 3Psh (Table 1, Figs. 3a, and 3b).

Line trawl (i.e. longline) catches dominated the fixed gear landings over the period 1977-93, reaching a peak of over 20,000 t in 1981 and typically accounting for 40-50% of the annual total for fixed gear (Table 2, Fig. 4). In the post moratorium period, line trawls have accounted for 16-26% of the fixed gear landings. Gillnet landings increased steadily from about 2,300 t in 1979 to a peak of over 9,000 t in 1987, and remained relatively stable until the moratorium. Gillnets have been the dominant gear used for the inshore catch since the fishery reopened in 1997, with gillnet landings exceeding 50% of the TAC for the first time in 1998. Gillnets have typically accounted for 70-80% of the fixed gear landings since 1998. Gillnets accounted for a lower percentage of the fixed gear landings in 2001 (60%), partly due to a temporary management restriction in their use that was removed part way through the fishery following extensive complaints from industry. Gillnets have also been used extensively in offshore areas in the post moratorium period. Cod trap landings from 1975 up until the moratorium varied considerably, ranging from approximately 1,000-7,000 t. Since 1998, trap landings have been reduced to negligible amounts (< 120 t). Hand line catches were a small component of the inshore fixed gear fishery prior to the moratorium (about 10-20%) and accounted for about 5% of landings on average for the post moratorium period. However, hand line catch for 2001 shows a substantial increase (to 17% of total fixed gear) and this may reflect the temporary restriction in use of gillnets described above. Increases in the proportion of hand-line catch in some years (e.g. 2009, 2013) are likely due to buyers paying a higher price for hook-caught fish than for gillnet landings.

The spatial removal details of reported landings are reported in (Table 3). Of particular note is the fact that offshore catches in 3Pn3s were higher from December 2014 through to March 2015 than in other recent years.

Inshore landings are low early in the year (Table 3), arising mostly from by-catch of cod in other fisheries. The vast majority of landings from the inshore areas (3Pne, 3Pnb, and 3Pnc) are taken in June-November, with highest landings in June and July, particularly in 3Pnc. The inshore (3Pne, 3Pnb, and 3Pnc) has consistently accounted for most of the reported landings. These have typically been highest in Placentia Bay (3Pnc), ranging from 1 300 t to almost 11 000 t with 35-55% of the annual 3Ps catch coming from this unit area alone. In 2014 the landings from 3Pnc were 1673 t, representing 43% of the 3Ps total. Most of the offshore landings have come from 3Psh and 3Psf (Halibut Channel and the southeastern portion of St. Pierre Bank). Unit areas 3Psd, 3Pse and 3Psg have accounted for a very small portion of the total catch in recent years but totals for these areas were increased in 2014. Catches in these areas thus far in 2015 have again been very low. The breakdown of landings by unit area excludes landings by France from 2009 to present. Resource managers from France have reported that the majority of these landings are taken in either 3Psf or 3Psh, but the exact unit area is unavailable.

The 2013-14 (April 1 to March 31) conservation harvesting plan places various seasonal and gear restrictions on how the 3Ps cod fishery in Canadian waters could be pursued. For example, unit areas 3Pse and 3Psd were closed from November 15-April 15 of the following year to avoid potential capture of migrating cod from the Northern Gulf stock (NAFO Divisions 3Pn4RS) and all of 3Ps was closed from April 1 to May 14, a closure intended to protect spawning aggregations. Full details of these and other measures, which may differ among food sectors, are available from the DFO Fisheries and Aquaculture Management (FAM) branch in St. John's.

CATCH AT AGE

Estimates of the 2014 catch numbers at age were not available for the 2015 3Ps cod Regional Assessment Process due to a shortage of time/personnel for ageing commercial otoliths. Similar restraints at the French ageing facility prevented the availability of age estimates from French catches. At this point the potential to age all future commercial samples is unclear.

Estimates of numbers at age for the 2011-13 catch were revised as fish larger than 100 cm were inadvertently omitted from the 2014 analyses due to a programming error. The revisions resulted in only minor changes in catch at age estimates. Generally, there were slight reductions observed in both the numbers and weights at age across the ages incorporated into modelling (3-12).

Revised detailed catch-at-age estimates for 2011-2013 are provided in Table 4 and the complete time series (1959 to 2013) of catch numbers at age (ages 3-14 shown) for the 3Ps cod fishery is given in Table 5. As noted in recent assessments (e.g. Shelton et al. 2006), there are discrepancies in the ratio of the sum of the product to landings over the 1959-76 period and attempts have been made to clarify these discrepancies by checking for missing catch and by adding plus group catch, but neither of these adequately explained the discrepancies. Until these discrepancies are resolved, it is recommended that catch at age prior to 1977 not be used as estimates of total removals in population analyses.

WEIGHT AT AGE

With no available ageing of commercial samples for 2014, weight-at-age could not be updated. The assessment uses approximate beginning of the year weights calculated from weight-at-age via the Rivard geometric mean method. In the absence of 2014 weight-at-age data, however,

approximate beginning of the year weights at age for 2016 were indeed estimated based on the geometric mean of the beginning of the year weights at each age for 2011-15.

The time series of mean weights at age in the 3Ps fishery including landings from the commercial and food fisheries and the sentinel surveys are given in Table 6a and Fig. 5, while beginning of the year weights at age are given in Table 6b and Fig. 7. Estimates of mean weights at age are derived from sampling of the catches stratified by gear type, unit area and month. Seasonal age length keys are applied to length frequency data to age the catch and calculate proportions at age. Weights at age are calculated using a length-weight relationship for cod.

For young cod (ages 3-6), weights at age computed in recent years tend to be higher than those in the 1970s and early 1980s (Table 6a, Fig. 7). The converse is generally true for older fish. Sample sizes for the oldest age groups (≥ 10) have been low in recent years due to the relative scarcity of old fish in the catch. The extremely low weights at age for ages greater than 10 could be related to these low sample sizes. Interpretation of trends in weights at age computed from fishery data is difficult because of annual year variability in the proportion of age caught by gear, time of year, and location.

SENTINEL SURVEY

The sentinel survey has been conducted in 3Ps since 1995 and there are now nearly complete years of catch and effort data. Sentinel activity for 2016 was ongoing at the time of the assessment; this data will be reviewed in subsequent years. The sentinel survey continues to produce a time series of catch/effort data and biological information collected by inshore fixed harvesters at various inshore sites along the south coast of Newfoundland. Sentinel fishery typically fish a control and an experimental site; the location of the control site is fixed, whereas the location of the experimental site can change only within the local area. In 2016, there were 11 active sites in 3Ps, using predominantly gillnets (5½" mesh) in unit area 3Psu (Placentia Bay) and line trawls in 3Psb and 3Psw (Fortune Bay and west). One 5½" gillnet was also fished at each of 5 sites in Placentia Bay one day per week. Fishing effort was low in 1998 (6 weeks), 2003 and 2004 (8 weeks each), than most other years (9-12 weeks), but since 2005 an average of 10 weeks has been maintained. Most fishing takes place in fall/early winter. Catch rates for 5½" gillnets in 2016 remained low and were similar to those recorded since 2003. Line trawl catch rates have declined and have been below the series average for the past 5 years.

As in previous assessments, an age-disaggregated index of abundance was produced for gillnet (5½" mesh) and line trawl sampling. There is insufficient data from the 5½" gillnets to develop a standardized index for this gear.

STANDARDIZED SENTINEL CATCH RATES

The catch from 3Ps was divided into cells defined by gear type (5½" mesh gillnet and line trawl), area (unit areas 3Psu, 3Psb, and 3Psw), year (1995-2016) and quarter. Age-length keys (ALKs) were generated for each cell using fish sampled from both the fixed and experimental sites; however, only fish caught at the fixed sites were used to derive the catch rate indices. Length frequencies and ALKs were combined within cells. The numbers of fish at length are assigned an age proportional to the number at age for that particular cell-length combination. Fish that were not assigned an age because of lack of information within the initial cell were assigned an age by aggregating cells until the data allowed an age to be assigned. For example, if there are no sample data in a quarter then quarters are combined to half year, half years are combined to year. If an age still cannot be assigned from areas are combined for the year. Since 2003, there are considerably fewer otoliths available for aging; annual sample sizes range between 240 and

deployed to target local aggregations. For inshore fisheries, catch rates can also be strongly influenced by annual variability in the extent and timing of inshore as well as along shore cod migration patterns. Similarly, the changes in management regulations, particularly the switch from a competitive fishery to Individual Quotas (IQs) and for some vessels the need to fish cod as bycatch to maximize financial return, can have a strong influence on catch rates that is unrelated to stock size (DFO 2008b). Consequently, inshore commercial catch rate data must be interpreted with caution. Despite these issues, the initial declines in gillnet and line trawl catch rates following the re-opening of the fishery in 1997 were cause for concern. The remarkable consistency in gillnet catch rates since 1998, despite the changes in resource abundance and management regulations, has not yet been explained. The decrease in modelled catch rates for line trawls since 2008 may in part be reflecting the reduced availability of the 1997 and 1998 year classes in the inshore catch, as the numbers of fish in these cohorts decline. Subsequent year classes have generally not been as strong, and catches would be more comprised of younger (and hence lighter) fish.

INDUSTRY LOGBOOKS (> 35 FT SECTOR)

The spatial distributions of both landings and unstandardized catch rates over 1998 to 2014 were determined using logbook data from the > 35' fleet. Data on landings and catch rates for otter trawls, gillnets and linetrawls were summarized in blocks at a resolution of 10 by 10 minutes of latitude and longitude (Fig. 10a-f) where there was sufficient data (arbitrary minimum of five per cell). The number of logbook records available for analyses has been variable over time. However, the number of gillnet sets recorded in logbooks were comparatively lower after 2008 than earlier in the time-series (Table 8). For all three gears, there was substantial spatial concentration in landings and a reduction in the number of areas reporting high landings over the time-series. Median catch rates per block were calculated for those logbook records that included duration (soak time) and limited to soak times typically observed for each gear type, based on analyses of observed frequency distributions. From 1998 to 2013, otter trawl catches were consistently high in the Halibut Channel and they were also high in areas of St. Pierre Bank during most years (Fig. 10a). Otter trawl catches declined in the Halibut Channel from 2010 to 2013. During 2014, effort was low by otter trawlers on St. Pierre Bank and while there was increased effort in the Halibut Channel, only low or moderate catches were reported there (Fig. 10a). Using all available data (including records without positional data) median catch rates for otter trawls were variable without trend for the time-series (Fig. 11). Intra-annual variability in otter trawl CPUE (5th and 95th percentiles, Fig. 11) was much lower post-2008 relative to pre-2008, consistent with results from the 10 x 10 minute analyses that showed that after 2008, fewer sets were conducted outside of the areas where high catch rates were reported previously (Fig. 10a). Catch rates in gillnets were highest in Placentia Bay and on St. Pierre Bank from 1998 to 2007, but since 2007 the highest catch rates were typically reported only on the bank (Fig. 10a). Overall, trends in gillnet catch rates declined from 1998 to 2001 and remained at a low level since then (Fig. 11). Generally, these results are consistent with those from the Sentinel Survey. Spatial trends differed between gillnets and linetrawls. Catch rates by linetrawls were variable without trend at most locations except in the Halibut Channel where catch rates were typically among the highest reported (> 1.0 kg per hook) up to 2010, but only low to moderate catch rates were reported there during 2013 and 2014 (Fig. 11f). Median catch rates in linetrawls remained similar among years over the entire time-series (Fig. 11), despite spatial shifts in effort. How trends in catch rates relate to stock status is unknown, particularly considering variable or declining effort.

TAGGING EXPERIMENTS / EXPLOITATION RATE

Tagging of adult (> 45 cm fork length) cod in Subdiv. 3Ps was initiated in 1997 and has continued through 2015. The objectives of the tagging study are to provide information on movement patterns of 3Ps cod as well as obtain ongoing estimates of exploitation rates (% harvested) on different components of the stock. Tagging efforts in 3Ps were reduced during 2005-11 with releases only in Placentia Bay (3Psc) during 2008-11 and there has been no tagging in the offshore regions of 3Ps since 2005 (Table 9a). Ho ever, during 2012-13 efforts were made to expand the tagging program under the auspices of a Fisheries Improvement Program (FIP) conducted by various levels of Government, Industry, and the WWF. The number of tags released was increased to 2,340 in 2012 and 3,951 in 2013, with coverage expanded to include a broader portion of the stock area (3Psa, 3Psb, 3Psc). Attempts to tag in the offshore were also made but these proved unsuccessful. In 2014, the number of tags released declined to 971 and coverage was again restricted to 3Psb and 3Psc. A brief synopsis of results from recent tagging is provided below.

Over 2009-10, approximately 300 tags were returned annually (Table 9b). Fewer tags were returned in 2011 and 2012 (133 & 190, respectively), resulting from both reductions in landings and the restricted spatial extent of releases, but returns have increased in 2013 (238) as a consequence of increased tagging effort. The percentage of returns coming from participants in the recreational fishery ranged from 4-11% during 2007-13 (Table 9b). Sufficient numbers of tags have been returned to estimate annual tag reporting rates (fraction of captured tags returned) using mixed-effects logistic regression (Cadigan and Brattey 2006). Inter-annual variations are relatively small with no trends over time (Fig. 12). Reporting rate for the offshore portion of 3Ps in 2013 was 0.62 and for the inshore was 0.72. Corresponding values for 2014 were 0.65 and 0.70, respectively.

The methods and estimates of the average annual exploitation rates (harvest rates, in percent) for cod tagged in different regions of 3Ps are described in detail elsewhere (Brattey and Cadigan 2004, Brattey and Healey 2003, 2004, 2005, 2006, Cadigan and Brattey 2003, 2006, 2008). However, results on size-specific exploitation rate from recent releases showed that although exploitation has been low in Placentia Bay, exploitation rate increases considerably with fish length, particularly for those sizes which are fully selected by the predominantly gill-net fishery. In the previous assessment, a comparison of exploitation rates across various size groups indicated that despite an overall low exploitation rate, larger cod (> 65 cm) were subject to higher exploitation rates. In 2013 harvest rates for cod tagged in Placentia Bay were broadly similar among cod size groups ranging from 13-16%; for those tagged in Fortune Bay the range was 19-25%. In 2014 harvest rates ranged from 10-16% in Placentia Bay, and from 11-21% in Fortune Bay. These exploitation rates are modest, but given that only about half of the TAC was taken in both 2013 and 2014, harvest rates would have been substantially higher if the full TAC was taken.

With respect to migratory patterns and stock distribution, recent tagging results (not shown) generally agree with previous findings (Brattey and Healey 2004, 2005, 2006), and indicate restricted mixing of cod from different portions of the 3Ps stock area. In particular, cod tagged in western 3Psa tended to show strong association with 3Pn, whereas those tagged on the eastern side of the Hermitage Channel of 3Psa tended to move eastwards into Fortune Bay (3Psb). Among cod tagged in Placentia Bay a small percentage (2.7% of 566 recaptures during 2011-14) was recaptured from the neighbouring stock area in Divs. 3KL. Cod tagged inshore tended to show limited movement to offshore portions of the stock area. The limited mixing of inshore cod in particular make it difficult to determine whether inshore stock indices (Sentinel survey) are reflecting trends in the stock as a whole, or mainly of inshore components of the

stock. Trends in the indices differ between inshore and offshore and remain difficult to reconcile with the tagging results.

RESEARCH VESSEL SURVEY

Stratified-random surveys have been conducted in the offshore areas of Subdiv. 3Ps during the winter-spring period by Canada since 1972 and by France over 1978-92. The two surveys were similar with regard to the stratification scheme used, sampling methods and analysis, but differed in the type of fishing gear and the daily timing of trawls (daylight hours only for French surveys). Canadian surveys were conducted using the research vessels A.T. Cameron (1972-82), Alfred Needler (1983-84; 2009-present), and Wilfred Templeman (1985-2008). From the limited amount of comparable fishing data available, it has been concluded that the three vessels had similar fishing power and no adjustments were necessary to achieve comparable catchability factors, even though the A.T. Cameron was a side trawler. The CCGS Teleost has also been used during exceptional events (e.g. severe mechanical issues on regular survey vessel), and any potential vessel effect is unaccounted for. Cadigan et al. (2006) found no significant differences in catchability for several species, including cod, between the Wilfred Templeman and Alfred Needler research vessels. Surveys by France were conducted using the research vessels Cyros (1978-91) and Thalassa (1992) and the results are summarized in Bishop et al. (1994).

The Canadian research vessel surveys from 1983 to 1995 employed an Engel 145 high-rise bottom trawl. In 1996, research surveys began using the Campelen 1800 shrimp trawl. The Engel trawl catches for 1983-95 were converted to Campelen 1800 shrimp trawl-equivalent catches using a length-based conversion formulation derived from comparative fishing experiments (Warren 1996; Warren et al. 1997; Stansbury 1996, 1997).

The stratification scheme used in the DFO RV bottom-trawl survey in 3Ps is shown in Fig. 13. Canadian surveys have covered strata ranging down to 300 fathoms (ftm) in depth (1 fathom = 1.83 meters) since 1980. Five new inshore strata were added to the survey in 1994 (stratum numbered 779-783) and a further eight inshore strata were added in 1997 (numbered 293-300) resulting in a combined 18% increase in the surveyed area. Beginning in the 2007 assessment, new indices using survey results from the augmented survey area were presented for the first time. Two survey time series are constructed from the catch data from Canadian surveys. The index from the expanded surveyed area that includes new inshore strata is referred to as the "All Strata < 300 ftm" index and the time series extends from 1997 onwards. The original smaller surveyed area is referred to as the "Offshore" survey index and the time series that incorporates a random stratified design extends from 1983-present.

The timing of the survey has varied considerably over the period (Table 10, Fig. 14). In 1983 and 1984 the mean date of sampling was in April, in 1985 to 1987 it was in March, and from 1988 to 1992 it was in February. Both a February and an April survey were carried out in 1993; subsequently, the survey has generally been carried out in April. The change to April was aimed at reducing the possibility of stock mixing with cod from the adjacent northern Gulf (3Pn4RS) stock in the western portion of 3Ps. The stock mixing issue is described in more detail in previous assessments (e.g., Brattey et al. 2007). Due to extensive mechanical problems with the research vessel, the survey in 2006 was not completed: only 48 of 178 planned sets were completed. Therefore, results for 2006 for the full survey area are not considered comparable to the remainder of the time-series. All subsequent surveys were considered complete. The 2015 survey completed 173 of the intended 178 fishing sets. All index strata were covered.

Abundance, Biomass, and Distribution

Trends in the abundance index and biomass index from the RV survey are shown for the offshore (i.e. index strata only: those strata of depth ≤ 300 ftm, excluding the new inshore strata) and the all strata area (Fig. 15). The trawlable abundance index declined from 88.2 million in 2001 to 38.7 million in 2008, the longest period of consistent decline in the entire time-series. However, the index has generally been higher during 2009-15. The 2013 estimate was particularly high, but was followed by a subsequent large decline for the 2014 and 2015 estimates which are around the 1997-2015 average. The trawlable biomass estimate has been variable for much of the post-moratorium period, but shows a general declining trend over 1998-2015, with the exception of a high value of 83,000 t in 2013.The survey biomass estimate for 2015 was 36,900 t and slightly above the time series average.

The trends and degree of variability in the combined inshore/offshore survey are almost identical to those of the offshore survey in spite of the 18% increase in surveyed area; the only exception is in 2005 when the combined inshore/offshore survey shows higher biomass and abundance due mainly to a large estimate from inshore stratum 294 (see Tables 11 and 12).

Survey indices of cod in 3Ps are at times influenced by "year-effects", an atypical survey result that can be caused by a number of factors (e.g., environmental conditions, movement, degree of aggregation, etc.) which may be unrelated to absolute stock size. The time series for abundance and biomass from 1983 to 1999 show considerable variability, with strong year effects, for example, the 1995, 1997 and 1998 surveys when compared to those from adjacent years. The 1995 estimate is influenced by a single large catch contributing 87% of the total biomass index and therefore has a very large standard deviation. The 1997 survey values were the lowest observed in the time series, which goes back to 1983, being less than half of the 1996 index. The size composition of fish in the 1997 RV survey suggested that this survey did not encounter aggregations of older fish, yet these fish were present in the 1996 survey and in subsequent commercial, sentinel, and survey catches.

There are strong indications that the 2013 survey may have been influenced by a year effect. In 2013, a large single catch of fish on Burgeo Bank resulted in >50% of the overall biomass being located in this particular area (Fig. 16) and causing a large spike in the survey indices for that year. A similar phenomenon occurred in the 2015 survey with a single large set on Burgeo Bank accounting for 38% of the biomass index. The fact that single large fishing sets have heavily influenced survey indices in two out of the last three years is a concern for the assessment and the sporadic appearance of high numbers of fish on Burgeo Bank is not fully understood. Another clear sign of a year-effect is the fact that the 2013 RV survey estimated that the abundance of multiple cohorts increased compared to observations of these same cohorts at one age younger in 2012. For at least some cohorts, this change is largely influenced by the single large survey catch described above. The number of fish in a cohort cannot increase as it ages (without immigration) and when analyses suggest that such an increase has occurred it is considered evidence for a year effect. In the 2013 survey, the 2011 year class (age 2 fish) was estimated to be by far the strongest in the times series. The subsequent two assessments have downgraded the estimated strength for this year class but it still appears strong relative to other recent year classes.

To further investigate whether there have been annual shifts in the distribution of the stock at the time of the survey, trends in the proportion of the total abundance observed in three different regions of the stock area were compared. The areas were (see Fig. 17): the inshore (strata 293-298, and 779-783), the Burgeo area (Hermitage strata 306-309, and 714-716), and the eastern area (remaining strata). Data from the combined inshore/offshore survey were used and the Campelen trawl was fished in all these surveys. The proportions were variable (Fig. 18), with

typically 30-70% observed in the larger eastern area, 15-60% in the Burgeo area, and around 10-25% in the inshore area. Part of the variation in the spatial composition of the index is due to year effects, often resulting from a small number of survey sets with very large catches. For example, the value for 1998 is high due to several large catches on Burgeo Bank and vicinity that may have included fish from the neighbouring northern Gulf (3Pn4RS) cod stock.

The spatial distribution of catches of cod during the 2015 survey was examined, for all ages combined (Fig. 19a, b, also includes 2012 to 2014 survey results for comparison) and separately for ages 1-12 (Fig. 19c). Previously it has been demonstrated (Healey et al. 2011a, Brattey et al. 2007) that cod tend to be caught over a considerable portion of NAFO Subdiv. 3Ps with the largest catches typically in the southern Halibut Channel area, on Burgeo Bank and vicinity, and within Fortune Bay. However, cod tend to be consistently scarce in the deep water below the mouth of Placentia Bay and in the inner reaches of Hermitage Channel. Increased catches of cod on Burgeo Bank were evident in 2015 and 2013.

Distribution plots of age-disaggregated survey catches from the 2015 survey (Fig. 19c) indicate low catches of one year old cod. It is important to note that due to their small size, one-year old cod are not fully selected by the trawl. However, the fact that survey catches of one year olds in 2015 appears much reduced relative to other recent survey years may be an early indication of a poor year-class. Two year old cod were found over most of the surveyed area, whereas the distribution of cod older than two years was restricted primarily to the Burgeo Bank/Fortune Bay area as well as the Halibut Channel. Almost no fish older than nine years were observed in the 2015 survey.

Age Composition

Survey numbers at age are obtained by applying an ALK to the numbers of fish at length in the samples. The current sampling design for cod in Subdiv. 3Ps requires that an attempt be made to obtain 2 otoliths per centimeter from each of the following locations: Northwest St. Pierre Bank (strata 310-314, 705, 713), Burgeo Bank (strata 306-309, 714-716), Green Bank-Halibut Channel (strata 318 319, 325 326, 707-710), Placentia Bay (strata 779-783) and remaining area (strata 315-317, 320-324, 706, 711-712). This spatial stratification ensures sampling is distributed over the surveyed area. The otoliths are then combined into a single ALK and applied to the survey data. These data can be transformed into trawlable population abundance at age by multiplying the mean numbers per tow at age by the number of trawlable units in the survey area. This is obtained by dividing the area of the survey by the number of trawlable units. For the "offshore" survey in 3Ps, the survey area is 16,732 square nautical miles including strata out to 300 ftms (and excluding the relatively recent inshore strata added in 1997). The swept area for a standard 15 min tow of the Campelen net is 0.00727 square nautical miles. Thus, the number of Campelen trawlable units in the 3Ps survey is $16,732 \div 0.00727 = 2.3 \times 10^6$. For the expanded survey area, there are approximately 2.7×10^6 trawlable units.

The mean numbers per tow at age in the DFO RV survey are given in Table 13 and results for ages 1-15 are shown in the form of standardized "bubble" plots in Fig. 20. Cod up to 20 years old were not uncommon in survey catches during the 1980s, but the age composition became more contracted through the late 1980s and early 1990s. In fact, few cod aged 15 or older have been sampled during surveys in the past two decades and none have been sampled in the last three years.

In recent years, much attention has been focused on the 2006 year-class. Over 2007-11, survey results for this year-class were much greater than average (at ages 1 through 5). However, subsequent surveys have suggested the numbers at age for the 2006 year-class at older ages to be near or below average. The age 1 survey index for the 2012 survey, representing the 2011

year-class, was much greater than the time-series average. This year-class has continued to look strong in subsequent surveys.

Size-at-Age (Mean Length and Mean Weight)

The sampling protocol for obtaining lengths-at-age and weights-at-age has varied over time (Lilly 1998), but has consistently involved stratified sampling by length. For this reason, calculation of mean lengths and weights included weighting observations by population abundance at length (Morgan and Hoenig 1997), where the abundance at length (3-cm size groups) was calculated by areal expansion of the stratified arithmetic mean catch at length per tow (Smith and Somerton 1981). Only data from 1983 onward are presented.

Mean lengths-at-age were updated using the 2015 survey data. For ages older than age 3 there was a general decline in length-at-age from the early 1980s to the mid-1990s (Table 14, Fig. 21a). For most ages there was an increase in length-at-age from the mid-1990s through the mid-2000s, followed by a period of lower length-at-age in recent years. In 2015 length-at-age increased compared to 2014 for about half of the ages examined.

Annual variation in mean length at age was examined using deviation from the average as a proportion over the time series for each age. The average mean length at age from 1983 to 2015 was calculated for each age. Deviation was calculated for each age in each year by subtracting the mean for the age for the time series from the annual observation for that age and then dividing this by the mean for that age. Ages 3 to 9 were included. Mean length at age was greater than average in the mid-1980s. It showed a declining trend until the mid-1990s when it was below average. Mean length-at-age subsequently increased. Length-at-age has been lower than average in 6 of the last 8 years and remains well below average in 2015. The last 3 years are 3 of the 4 lowest in the time series (Fig. 21b).

Values for mean weight at age were updated with data from the 2015 survey (Table 15, Fig. 22a). There was an increase in weight-at-age from the mid-1990s through the mid-2000s, but data from 2007-15 surveys suggest that mean weight-at-age was mainly lower than the mid-2000s. Mean weight-at-age was greater than average in the mid-1980s and generally declined to very low levels in the mid 1990's (Fig. 22b). As with mean length-at-age, mean weights-at-age increased after that time to about 2000. Weight-at-age since 2005 has been generally lower with 6 of the last 8 years below average. Weight-at-age in 2013 and 2014 were the lowest in the time series. Weight-at-age increased in 2015 but was still well below average and 5th lowest in the time series.

Condition

Relative gutted condition (relative K) and relative liver condition (relative LK) were calculated from survey data. It has been shown that the timing of the survey affects estimates of condition for 3Ps cod (Lilly 1998) and so only estimates from April surveys beginning in 1993 were estimated. A length gutted weight relationship was estimated, and the condition index is then observed condition divided by the condition predicted from the length weight regression for a fish of that length. Relative liver condition was calculated in a similar fashion using a liver weight-body length regression. However, evaluation of the model fit indicated that a simple linear regression did not provide an adequate fit to the data. In addition, liver weight data for fish under 30 cm and greater than 120 cm were highly variable. Therefore, the analyses were restricted to fish 30-120 cm in length and the regression was log(liver weight) = intercept + b1*log(length) + b2*(log(length)*log(length)). Both gutted and liver condition increased to about 1998 and then were lower until 2004 with a spike in 2005 (Fig. 23). Gutted condition reached a low in 2008 but has increased steadily since that time to reach above average levels in 2013,

however it declined again in 2014 and remained low in 2015 Liver condition declined substantially in 2014 and most years since 2007 have been below average.

In conclusion, mean length-at-age and mean weight-at-age have both been low over the last 3 years and indices of condition have been low in the last 2 years.

Maturity

The sampling design used to gather biological data to study maturation trends and an overview of maturity and fecundity research relating to 3Ps cod can be found in Brattey et al. (2008).

Annual estimates of age at 50% maturity (A50) for females from the 3Ps cod stock, collected during annual winter/spring DFO RV surveys, were calculated as described by Morgan and Hoenig (1997). Trends in age at 50% maturity are shown in Fig. 24a (only cohorts with a significant slope and intercept term are shown); parameter estimates and associated standard errors for the 1954 to 2010 cohorts are given in Table 16, and the model did not adequately fit data for subsequent cohorts as most of these fish remain immature. Age at 50% maturity declined rapidly for cohorts from the 1980s and remained low for cohorts from the 1990s. There was a slight increase in A50 to ~ 5.5 years for cohorts of the early 2000s but values for the most recent cohorts have once again dropped below 5 years (Fig. 24a). Given that the estimation is conducted by cohort, estimates for the most recent cohorts may be revised slightly in future years as additional data are collected. Males show a similar trend in A50 over time (data not shown), but tend to mature about one year earlier than females.

Annual estimates of the proportion mature at age are shown in Table 17; these were obtained from the cohort model parameter estimates in Table 16. The estimates of proportion mature for ages 4-7 show a similar increasing trend (i.e., increasing proportions of mature fish at young ages) through the late 1970s and 1980s, particularly for ages 5, 6, and 7 (Fig. 24b). Due to the low age at 50% maturity, the proportions mature at age are quite high.

The time series of maturities for 3Ps cod shows a long-term trend as well as considerable annual variability. Such variations can have substantial effects on estimation of spawner biomass. Further, the age composition of the spawning biomass may have important consequences in terms of producing recruits (see Brattey et al. 2008).

Cohort Analyses

During the 2006 assessment of this stock, it was agreed that sequential population analyses of 3Ps cod should be discontinued, primarily due to inconsistent trends in the index data available (poor correlations within and between surveys) and poor model fit (strong year-effects and poor precision in estimated parameters) (For additional discussion, refer to DFO (2006, 2007) as well as Brattey et al. (2008)). In addition, the accuracy of the total landings captured by the commercial catch data has been questioned during assessment meetings (e.g., Shelton et al. 1996, DFO 2010). In the 2007 assessment of this stock, Brattey et al. (2008) provided estimates of instantaneous rates of total mortality (Z) for 1997-2007 as computed directly from the combined DFO RV survey. A debate on smoothing these annual estimates of total mortality during the winter 2009 zonal assessment meeting led to the exploration of cohort modeling of the survey data to provide structure to the smoothing. Consequently, a survey-based (SURBA) model based upon the work of Cook (1997) was implemented and it provides estimates of total mortality, relative recruitment strength, and relative estimates of total and spawning biomass from the DFO RV survey (see Cadigan 2010).

Data for ages 1-12 from the DFO RV expanded index were used in the SURBA, including an adjustment for the 1983-96 survey indices to account for the inshore area that was not sampled

in these years. However, data for ages 1 and 2 over 1983-95 are zero-weighted in estimation, due to concerns of potential biases in RV data conversion of these age groups (this conversion accounts for a change in the trawl gear after the 1995 survey). The age-specific adjustment is the ratio of the average survey index for the expanded area (1997-present) to the average offshore survey index over the same period (see Fig. 25). These adjustment factors are applied to the survey index at age over 1983-96. As younger fish are generally found in greater abundance in the near-shore, this ratio exceeds one at ages 1-3. For fish older than age 3, the adjustment is less than 1 and generally declines with age.

The age-disaggregated cohort model assumes that total mortality experienced by the population can be separated into vectors of age effects s_a and year effects f_y (such that $Z_{a,y} = s_a \times f_y$). Estimation (lognormal likelihood) minimizes the difference between the predicted and observed survey index over all ages and years, with penalties applied to impose a degree of smoothing on the estimated age and year effects. However, the model was speculative in that it could not reliably estimate survey selectivity, and fixed values are applied. Survey selectivity is assumed to be constant for ages 4 +, that is, selectivity is "flat-topped". The age effects estimated in deriving a recruitment index from the age 1-4 survey data during a previous assessment of this stock (Healey et al. 2013) were used to provide some objectivity in the survey catchabilities supplied to the model for the ages which are not fully-recruited. An alternate assumption assuming "dome" selectivity was explored in a previous assessment (Healey et al. 2011a). It has been argued that best-practice is to assume flat-topped selectivity (Northeast Fisheries Science Center 2016) unless there is evidence otherwise.

Detailed model specification, sensitivities of results to modeling assumptions, and estimation procedures applied in developing this model are documented in Cadigan (2010). PROC NLMIXED in SAS/STAT™ software is used to estimate parameter values and associated uncertainty.

An updated run of the previous assessment model formulation was presented. Estimated age-specific patterns in mortality indicate an increasing trend in relative total mortality to age 9, after which relative mortality decreases slightly (Fig. 26). Cohort analyses of the RV data indicated that SSB declined by 58% over 2004-09 (Fig. 27a). Median SSB was estimated to be at the LRP in 2008 and below the LRP in 2009. SSB increased considerably over 2009-12 but has since declined. The 2014 and 2015 estimates are approximately 1.4 times higher than the LRP. The probability of being below the LRP in 2015 is low (~0.05). As a result of improved recruitment and recent increases in the proportion mature-at-age, 82% of the 2015 SSB is comprised of fish of ages 4-7. The reliance on young spawners may be a concern given that younger fish produce fewer and smaller eggs/larvae that may have reduced survival. Young fish also spawn over a narrower time frame which decreases the probability of overlap between larval emergence and peak plankton abundance and can result in reduced survival.

Total mortality rates reflect mortality due to all causes, including fishing. Estimated total mortality from a cohort model (Fig. 27b) for ages 5-10 has generally been increasing since 1997 and current estimates are near the time series maximum. The average estimated mortality over the last three years (2012-14) is 0.65 (48% annual mortality), which is high especially considering that reported landings have been about half the TAC over this time period. The total mortality values are weighted by population number at each of ages 5-10. It remains unclear whether or not these mortality rates are sustainable over the longer term.

Recruitment (Fig. 27c) has improved over the last decade with most cohorts at or above the time series (1983-2014) average. Indications are that the 2011 and 2012 cohorts are among the strongest in the time-series. However, it should be noted that the uncertainty around the

estimates for these recent cohorts is quite high and the estimates may be revised as additional data are collected.

Model diagnostics are similar to results obtained during the previous assessment. There is evidence of the year-effects as described in the survey results section, particularly those during the mid-1990s (multiple years of almost all negative residuals). Otherwise, there are no indications of systematic model fit issues (Fig. 28).

The assessment of 3Ps's cod has been subject to retrospective revisions of estimates from previous years with the addition of a new year's survey data (Fig. 29). For example, in the 2013 assessment the SSB demonstrated a steadily increasing trend from 2009-13 with the 2013 estimate being twice the level of the LRP. In the 2014 assessment, however, SSB leveled off after 2012, with the 2013 estimate being 1.6 times the level of the LRP. In the 2015 assessment, the 2013 SSB estimate has been further downgraded to 1.5 times the level of the LRP. Likewise, the previous assessment estimated the 2014 SSB to be 1.6 times the level of the LRP, whereas this has been adjusted to approximately 1.4 times the LRP in the current assessment. Retrospective revisions are not uncommon in cohort models, which use annual information to predict the abundance of multiple cohorts. The relatively large revision to the SSB estimates occurred because the 2014 and 2015 survey estimates have decreased considerably from the large (and unexpected) values of the 2013 survey. Several recent year-classes were revised downwards, with the greatest revision to the 2011 year-class. Total mortality has increased considerably since 1997 but there has been a retrospective revision of the trend in mortality in recent years. The 2013 assessment suggested mortality to have decreased slightly since 2009, the 2014 assessment estimated mortality to have remained somewhat steady since 2009, and the most recent assessment estimates that mortality has continued to increase since 2009 (Fig. 29).

Projection of the stock to 2016 was conducted assuming mortality rates will be within ± 20% of current values (2012-14 average). More specifically, five projection scenarios were conducted, scaling current total mortality by each of 0.8, 0.9, 1.0, 1.1, and 1.2. A three year geometric mean of recruitment and three year average of weight-at-age were used. The proportions mature at age were projected forward from the cohort-specific model estimates.

Projection scenarios indicate that the 2016 SSB will increase from the 2015 estimate, with median 2016 relative SSB projections ranging from 1.7 to 2.1 (Fig. 30). In each of the scenarios, the probability of being below the LRP in 2016 is low (≤ 0.05). By 2016 the strong 2011 year class will be 5 years old and under all projection scenarios examined will constitute at least 50% of the 2016 SSB, indicating an extremely high reliance of the population on very young spawners.

ECOSYSTEM CONSIDERATIONS

The structure and trends in the fish community of NAFO Subdiv. 3Ps were analyzed on the basis of Research Vessel (RV) biomass, abundance, and biomass/abundance (BA ratio) indices derived from DFO winter and spring surveys in the 1982-2015 period. These analyses involved the characterization of the community by fish functional groups which, for the most part, are defined considering the species size and general trophic characteristics. These functional groups are small, medium, and large benthivores, piscivores, planktopiscivores, planktivores, and shellfish (this last group only includes commercial shellfish species, like Pandalus shrimps and Snow Crab). Reliable data on shellfish are only available since 1995, when the fishing gear used in the survey was changed from an Engels to a Campelen trawl. Since there are no conversion factors available for all species, many analyses were carried out partitioning the times series into Engels (1982-95) and Campelen (1996-2015) periods.

Changes in total biomass and internal structure of the fish community were described on the basis of trends over time, and analyzed using Bray-Curtis similarity matrices from standardized and non-standardized RV biomass data. Analyses from non-standardized data allow the consideration of differences in magnitude, while those from standardized data allow a focus on internal structure of the fish community. Hierarchical agglomerative cluster analyses, together with Similarity Profile permutation tests were used to identify significant clusters of years within the Engels and Campelen periods. Changes in abundance were described considering the trends over time by fish functional groups, while the changes in fish sizes were evaluated using normalized anomalies of BA ratios by functional group.

Food consumption by the fish community was explored using a suite of approaches aimed at estimating food requirements and/or average consumption rates (per unit of biomass) for different taxa. A total of 8 different consumption sets were defined considering different combinations of consumption models (daily ration and simple allometric models). All these models assume that consumers actually met their expected annual requirements, which could overestimate consumption, but also the expansion of consumption to the population/stock level is based on RV biomass estimates without catchability corrections, which may lead to underestimating consumption. Overall, these approaches considered together are not expected to provide a fine tuned estimate of consumption; instead, the goal is to produce a reasonable envelope for the order of magnitude of food consumption by the fish community.

Diet composition was studied using stomach content analyses from samples collected during DFO RV surveys. Diet studies focused on key fish species, including Atlantic cod. Other related information like the frequency of empty stomachs, and the meal size (approximated by the weight of the food remains in the stomach), were also examined.

Despite the issues associated with changes in timing of the survey (i.e. winter and spring), it is clear that the overall biomass of the fish community increased in the early 1980s, and later declined in the late 1980s and early 1990s (Fig. 31). This decline also involved changes in the structure of the fish community, and a general reduction in fish size (Fig. 32). Results from the cluster analysis of the 1982-1995 period indicate that the changes in community structure have a coherent temporal sequence, where significant clusters typically aggregate consistent periods of time (i.e. consecutive years).

Since the mid-1990s, the overall biomass of the fish community has not changed significantly, but abundance has. Overall abundance increased until 2013, and declined afterwards. These changes in abundance have been mainly driven by planktivores, and to a lesser extent planktopiscivores in the late 2000s (Fig. 31).

Notwithstanding the relative stability of the overall biomass level during the Campelen period (1996-2019), the biomass structure of the fish community has changed during this time. These changes have involved increases/decreases in biomass at the functional group level, but unlike earlier observations, the overall pattern of change in structure does not seem to follow any obvious temporal sequence. Still, trends among some functional groups are significantly correlated (e.g. small benthivores and shellfish are positively correlated, medium and large benthivores are also positively correlated). During this period, fish size (BA Ratio) also showed a further decline in the mid-2000s, and remains at that lower level to this day (Fig. 32).

Recent changes include clear declines in biomass in small benthivores, planktivores, and shellfish over the last five years (Fig. 31). Piscivores show a relatively stable overall biomass level, but experienced important changes in internal structure. Cod used to be the exclusive dominant species within this functional group, but silver hake has increased its dominance, and currently shows biomass levels similar to cod (Fig. 33).

Taking into account all these changes together, it seems that the fish community in SPA shows evidence of some level of internal structure and coherence, but it also shows signs of weakening in that internal cohesion in the most recent period. The causal pathway in recent years could be linked to increasing impact/export processes and/or increased variability in these fluxes. Therefore, and in terms of ecosystem identity, the mixing community in WATT Subdivision SPA possesses enough elements to characterise it as a functional ecosystem, but one that is heavily influenced by neighbouring systems (Orkney Islands, Outer Hebrides and Scottish Shelf).

Regarding the order of magnitude of consumption, the fish community in SPA is estimated to consume food in the range of 1–3 million tonnes per year. Within this envelope, piscivores are estimated to eat in the order of 200-600 thousand tonnes per year.

Cod diet in the spring of 2016 continues to be dominated by whole crab, with sandeel as the second most important prey (Fig. 5B). Predation on whole crab is more important in larger cod (Fig. 5D). Although time series of cod diet data in SPA are far from complete, the available evidence indicates that cod has a very variable diet in this region. This suggests that food availability may be highly variable, and potentially limiting.

In the 2015-16 period, other predators like American plaice, turbot, and Yellowtail flounder had sandeel as a dominant prey, capelin was also an important prey in some of these predators. None of them preyed upon whole crab to the same degree as cod (Fig. 5B).

When comparing SPA with neighbouring 6G for cod and other predators, it seems clear that although variable, sandeel is an important prey in the broader area, while the high reliance of cod on whole crab appears as a SPA-specific phenomenon.

Examination of meat sizes and frequency of empty stomachs indicate that current meat sizes are of similar or larger magnitude than the ones observed in the 1980s prior to the 1990s decline, while the frequency of empty stomachs is also low. Meat / cod were clearly smaller, and the frequency of empty stomachs much larger, during the mid-1990s. These observations suggest that availability of any food type may have been a factor in the early 1990s decline. Current status appears to be more likely related to food quality, although availability of higher quality food may also be at play.

In comparative terms, cod meat sizes are smaller in SPA than in the neighbouring 6J4N ecosystem. This observation gives credence to the interpretation that the variability in SPA cod diet could be associated with potential constraints in prey availability.

In summary, the SPA fish community can be considered a systematic habitat ecosystem functional unit, but it also appears susceptible to external influences. Ongoing warming trends, together with the increasing dominance of warm water species, recent declines in planktivores, and the reduced fish sizes across fish functional groups suggest that this ecosystem is undergoing structural changes, and potentially experiencing reduced productivity conditions. Although complete understanding of these changes, and their implications for processes like cod and white hake, are still lacking, the available evidence suggests that current productivity may be reduced. In this context, it would be strongly advisable to minimise higher than usual risk aversion in the management of these stocks.

EXPLOITATION AND ADVICE

The DFO survey covers most of the stock area and is designed to provide an index of stock size. Therefore, consistent with recent assessments, a survey model (SURBA) based on this survey was used to infer overall stock trends.

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TABLES

Table 1. Reported landings of cod (t) from NAFO Subdiv. 3Ps by country and for fixed and mobile gear sectors. Landings are presented by calendar year but note that since 2000 the TAC has been established for April 1-March 31. Catch estimates for 2015 are incomplete since the fishing year was in progress at the time of the assessment. See Healey et al. (2014) for pre-1960 data.

Year	Canada NL (Mobile)	Canada NL (Fixed)[1]	Canada Maritimes (All gears)	France SPM (Inshore)	France SPM (Offshore)	France Metro (All gears)	Others (All gears)	Total	TAC
1960	2,[illegible]	25,427	715	214	1,722	2,681	-	37,569	28,000
1961	2,[illegible]	26,[illegible]	2,321	333	3,769	3,736	-	38,892	30,000
1962	2,[illegible]	21,351	2,348	1,339	3,771	2,184	-	33,903	33,000
1963	2,133	23,915	2,593	943	4,775	4,238	-	38,451	33,000
1964	935	23,[illegible]	1,365	777	6,773	3,671	-	36,950	33,000
1965	4,525	24,[illegible]	2,476	542	9,423	8,644	-	51,367	41,000
1966	5,214	24,821	1,363	389	13,653	11,939	7	57,990	41,000
1967	4,133	26,735	2,517	551	15,309	9,965	-	59,204	41,000
1968	3,690	19,742	2,308	249	13,911	7,373	4	43,382	41,000
1969	3,334	23,208	2,361	339	9,542	892	-	39,540	35,400
1970	3,268	20,126	3,282	158	14,771	-	-	41,405	35,400
1971	3,916	21,779	2,139	204	15,595	-	-	43,569	35,400
1972	4,468	19,025	2,234	2	13,162	-	-	35,895	35,400
1973	1,947	11,978	1,351	-	-	-	-	15,216	20,000
1974	82	453	86	-	-	-	-	661	0
1975	36	679	63	59	-	-	-	821	0
1976	63	936	116	43	-	-	-	1,057	0
1977	138	7,594	79	449	1,191	-	-	9,420	10,000
1978	2,540	13,035	880	939	2,511	-	-	20,156	20,000
1979	3,359	21,139	614	921	2,549	-	-	27,997	30,000
1980	5,436	16,247	746	879	3,807	-	-	75,130	20,000
1981	2,182	11,187	936	675	1,675	-	-	16,546	15,000
1982	1,329	11,292	459	579	1,623	-	-	15,319	15,000
1983	1,861	12,439	413	734	1,643	-	-	15,260	15,000
1984	1,535	9,451	736	469	2,113	-	-	14,414	15,000
1985	1,840	9,937	519	617	1,941	-	-	14,770	15,000
1986	1,511	9,596	675	555	1,326	-	-	13,157	13,000
1987	1,339	9,303	394	520	1,503	-	-	12,959	13,000
1988	949	9,804	577	467	1,293	-	-	11,773	13,000
1989	1,759	5,870	193	243	1,684	-	-	9,762	11,500
1990	1,413	5,244	126	76	1,364	-	-	8,299	11,500
1991	1,350	4,048	303	476	693	-	-	6,876	11,500
1992	938	3,596	277	265	291	-	-	5,087	11,500
1993	379	2,690	174	369	768	-	-	4,366	11,500
1994[2]	472	4,139	537	279	1,158	-	-	6,745	13,225
1995[2]	879	1,803	135	249	674	-	-	3,736	13,490

[1]Provisional catches

[2]1995-2006 includes recreational and sentinel catch. 2007-15 does not include recreational catch

Table 2. Reported fixed gear catches of cod (t) from NAFO Subdiv. 3Ps by gear type (includes non-Canadian and recreational catch). See Healey et al. (2014) for pre-1980 data.

Year	Gillnet	Longline	Handline	Trap	Total
1960	5,493	19,331	2,545	2,077	29,446
1961	4,998	20,540	1,142	948	27,628
1962	6,283	13,574	1,597	1,929	23,383
1963	6,144	12,722	2,540	3,643	25,049
1964	7,275	9,580	2,943	3,271	23,069
1965	7,086	10,596	1,832	5,674	25,188
1966	8,668	11,014	1,634	4,073	25,389
1967	9,304	11,807	1,628	4,931	27,670
1968	6,433	10,175	1,469	2,449	20,526
1969	5,997	10,758	1,657	5,996	24,408
1990	6,948	8,792	2,217	3,788	21,745
1991	6,791	10,304	1,832	4,068	22,995
1992	5,314	10,315	1,330	3,397	20,356
1993	3,975	3,783	1,204	3,557	12,519
1994	90	0	381	0	471
1995	383	182	0	5	570
1996	467	158	137	10	772
1997	3,760	1,158	1,172	1,167	7,258
1998	10,116	2,914	308	92	13,430
1999	17,976	3,714	503	45	22,237
2000	14,218	3,100	186	56	17,561
2001	7,377	2,833	2,089	57	12,357
2002	7,827	2,309	775	119	11,030
2003	8,313	2,044	546	35	10,937
2004	7,910	2,167	415	15	10,508
2005	8,112	2,016	626	6	10,760
2006	7,590	2,698	314	2	10,603
2007[1]	7,287	2,374	445	11	10,116
2008[1]	6,636	2,482	341	21	9,480
2009[1]	4,052	1,644	612	36	6,344
2010[1]	4,013	1,182	296	2	5,493
2011[1]	2,910	882	221	19	4,032
2012[1,2]	3,089	670	192	10	3,961
2013[1,2]	1,939	457	270	14	2,680
2014[1,2]	2,760	1,066	331	38	4,195
2015[1,2,3]	1,444	196	207	9	1,856

[1]provisional

[2]excluding recreational catch

[3]As of September 30, 2015

Table 3. Reported monthly landings (t) of cod per unit area in NAFO Subdiv. 3Ps.

Year	Month	Inshore 3Psa	Inshore 3Psb	Inshore 3Psc	Offshore 3Psd	Offshore 3Pse	Offshore 3Psf	Offshore 3Psg	Offshore 3Psh	Total
2013	Jan	13.0	46.6	38.5	0.0	0.0	0.0	0.0	60.1	175.2
2013	Feb	19.9	56.4	44.8	0.0	0.0	0.0	0.0	88.2	193.0
2013	Mar	0.2	0.0	0.0	0.0	0.0	0.0	5.1	8.7	43.7
2013	Apr	0.0	0.0	0.0	0.0	0.0	0.0	3.2	43.6	18.1
2013	May	21.3	17.3	42.4	0.0	0.1	0.6	3.6	26.8	111.0
2013	Jun	45.1	51.4	492.2	0.0	0.5	0.0	1.9	0.0	591.1
2013	Jul	45.1	68.9	447.1	3.1	0.1	1.0	11.1	7.0	583.3
2013	Aug	1.8	26.3	77.0	0.0	0.0	0.6	1.2	0.0	106.9
2013	Sep	16.5	21.0	66.5	0.0	0.7	38.1	0.0	0.0	142.7
2013	Oct	24.5	36.8	141.5	0.0	0.0	127.0	0.0	0.9	343.9
2013	Nov	68.9	35.9	245.2	11.4	0.0	223.8	5.4	13.2	629.8
2013	Dec	16.2	9.9	78.4	0.0	0.0	54.6	0.0	0.0	133.0
2013	Total	272.4	370.5	1673.5	14.5	1.4	445.7	31.4	249.3	3058.7
2014	Jan	7.4	60.3	46.9	7.7	0.0	0.1	5.8	62.3	190.4
2014	Feb	8.8	35.0	58.1	6.1	0.2	0.0	70.5	38.2	216.9
2014	Mar	5.5	2.0	15.0	0.0	0.0	0.0	108.9	67.7	199.1
2014	Apr	0.1	0.0	0.0	0.0	0.0	0.0	21.5	21.9	43.4
2014	May	35.5	32.8	77.9	0.3	0.0	21.9	5.4	78.8	252.5
2014	Jun	46.5	75.3	600.0	15.6	7.9	69.1	11.7	51.4	877.5
2014	Jul	18.5	67.8	404.4	10.1	5.4	9.3	4.7	12.0	532.2
2014	Aug	5.6	18.0	183.2	0.0	4.9	17.0	0.5	1.6	230.7
2014	Sep	1.6	37.2	118.9	8.5	37.7	129.1	14.6	0.1	347.7
2014	Oct	7.8	67.0	119.9	46.2	18.0	216.3	43.6	6.4	525.1
2014	Nov	27.0	36.3	135.2	29.4	1.5	228.2	0.1	6.6	464.4
2014	Dec	21.5	125.2	258.2	0.0	0.0	11.3	11.8	362.7	790.9
2014	Total	185.8	557.0	2,017.6	123.8	75.6	702.2	298.9	709.8	4670.8
2015	Jan	26.2	131.2	90.0	0.0	0.0	8.75	0.0	419.68	675.8
2015	Feb	56.1	20.9	48.4	0.0	0.0	0.0	1.76	134.82	261.9
2015	Mar	4.0	0.0	14.3	0.0	0.0	1.10	0.0	297.69	317.1
2015	Apr	3.3	0.5	4.3	0.0	0.0	0.0	0.20	2.59	10.9
2015	May	38.4	37.3	59.9	0.0	0.0	0.0	0.0	0.0	135.7
2015	Jun	34.8	52.1	278.3	0.0	1.21	0.0	0.0	0.01	366.4
2015	Jul	19.0	80.0	469.0	0.0	0.31	0.38	0.0	0.0	568.7
2015	Aug	4.1	51.0	281.6	0.0	0.0	0.0	0.0	0.0	336.7
2015	Sep	0.1	25.6	40.5	0.0	0.0	0.0	0.0	0.0	66.2
2015	Oct	-	-	-	-	-	-	-	-	-
2015	Nov	-	-	-	-	-	-	-	-	-
2015	Dec	-	-	-	-	-	-	-	-	-
2015	Total	185.9	398.7	1286.2	0.0	1.5	10.2	2.0	854.8	2739.3

*French catch (2013 = 1134 t, 2014 = 1437 t, 2015 = 923 t) excluded since unit area not available.

Table 4. Estimates of average weight, average length and the total numbers (000s) and weight of 3Ps cod caught at age from Canadian and french landings during 2011-13 (Excludes recreational catch).

Year	Age	Average Weight (kg)	Average Length (cm)	Total Catch (000's)	Total Catch std error	Total Catch CV	Total Catch Weight (t)*
2011	1	0.23	30.01	15	0.01	0.51	0
2011	2	0.58	40.42	872	0.27	0.31	1
2011	3	1.07	48.47	30602	3.23	0.11	32
2011	4	1.06	48.85	136030	10.64	0.08	145
2011	5	1.37	53.04	838616	20.82	0.02	1152
2011	6	1.63	55.98	808873	22.38	0.03	1321
2011	7	2.18	61.44	853939	21.85	0.03	1853
2011	8	2.42	63.40	351441	13.73	0.04	851
2011	9	2.72	65.09	172333	10.16	0.06	468
2011	10	2.67	64.70	67828	6.75	0.1	181
2011	11	2.79	66.11	32978	4.88	0.15	92
2011	12	2.81	65.90	23441	3.69	0.16	66
2011	13	7.01	86.65	16763	2.7	0.16	117
2011	14	10.42	102.55	7807	0.68	0.09	81
2011	15	5.16	80.93	9443	3.81	0.4	49
2011	16	12.73	108.40	581	0.15	0.26	7
2011	17	15.39	118	68	0.03	0.5	1
2011	18	17.10	121.19	216	0.11	0.49	4
2011	19	-	-	0	-	-	0
2011	20	18.09	124.20	220	0.11	0.51	4
2012	1	0.06	19.00	1	0.00	0.02	0
2012	2	0.18	27.43	30	0.01	0.17	0
2012	3	0.77	44.18	8056	0.89	0.11	6
2012	4	0.93	46.91	65563	4.97	0.08	61
2012	5	1.39	52.96	183215	11.07	0.06	255
2012	6	1.95	58.98	675125	26.42	0.04	1315
2012	7	2.01	59.96	621312	27.64	0.04	1250
2012	8	2.17	61.06	396430	23.55	0.06	862
2012	9	2.75	65.52	146424	13.85	0.09	403
2012	10	3.31	69.30	62806	5.73	0.09	208
2012	11	3.59	70.75	22766	3.46	0.15	82
2012	12	2.65	64.96	30690	5.35	0.17	81
2012	13	4.33	73.71	6239	1.19	0.19	27
2012	14	3.51	69.32	10713	1.84	0.17	38
2012	15	7.72	92.65	3302	0.69	0.21	26
2012	16	7.23	89.33	792	0.38	0.48	6
2012	17	15.18	116.78	120	0.05	0.44	2
2012	18	12.04	109.00	78	0.00	0.02	1
2012	19	20.75	130.00	37	0.06	1.54	1
2013	1	-	-	0	-	-	0
2013	2	0.21	29.17	34	0.01	0.18	0
2013	3	0.63	41.64	6296	1.33	0.21	4
2013	4	1.18	50.47	153640	11.60	0.08	182
2013	5	1.57	55.48	430935	20.69	0.05	676
2013	6	1.86	58.53	331654	19.51	0.06	617
2013	7	2.14	61.14	488483	22.31	0.05	1044
2013	8	2.05	60.18	361214	19.03	0.05	740
2013	9	2.57	64.13	139756	11.60	0.08	359
2013	10	2.98	67.76	48664	6.68	0.14	145

Year	Age	Average Weight (kg)	Average Length (cm)	Total Catch (000's)	Total Catch std error	Total Catch CV	Total Catch Weight (t)*
2013	11	3.05	67.97	21621	5.56	0.26	66
2013	12	3.25	69.45	20534	4.71	0.23	67
2013	13	2.46	64.13	4990	1.79	0.36	12
2013	14	2.42	64.46	9231	3.42	0.37	22
2013	15	2.01	61.00	2061	1.37	0.67	4
2013	16	0.00	0.00	0	0.00	0.00	0
2013	17	0.00	0.00	0	0.00	0.00	0
2013	18	3.96	76.00	164	0.14	0.84	1

2011 * Total catch estimate (t) 6425, Total landings (t) 6877, SOP 0.93

2012 * Total catch estimate (t) 4622, Total landings (t) 5021, SOP 0.92

2013 * Total catch estimate (t) 3939, Total landings (t) 4129, SOP 0.95

Table 5. Numbers-at-age (000s) for the commercial cod fishery in NAFO Subdiv. 3Ps from 1959 to 2013 (ages 3-14 shown). Recreational catches excluded for 2007 onward (see text).

Year	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14
1959	1001	13940	7525	7265	4875	942	1252	1260	631	545	44	1
1960	567	5496	23704	6714	3476	3484	1020	827	406	407	283	27
1961	450	5586	10357	15960	3616	4680	1849	1376	446	265	560	58
1962	1245	6749	9003	4533	5715	1367	791	571	187	140	135	241
1963	961	4499	7091	5275	2527	3030	896	292	143	99	107	92
1964	1906	5785	5635	5179	2945	1881	1891	652	339	329	54	27
1965	2314	9636	5799	3609	3254	2055	1218	1033	327	68	122	36
1966	949	13662	13065	4621	5119	1586	1833	1039	517	389	32	22
1967	2871	10913	12900	6392	2349	1364	604	316	380	95	149	3
1968	1143	12602	13135	5853	3572	1308	549	425	222	111	5	107
1969	774	7098	11585	7178	4554	1757	792	717	61	120	67	110
1970	756	8114	12916	9763	6374	2456	730	214	178	77	121	14
1971	2884	6444	8574	7266	8218	3131	1275	541	85	125	62	57
1972	731	4944	4591	3552	4603	2636	833	463	205	117	48	45
1973	945	4707	11386	4010	4022	2201	2019	515	172	110	14	29
1974	1887	6042	9987	6365	2540	1857	1149	538	249	80	32	17
1975	1840	7329	5397	4541	5867	723	1196	105	174	52	6	2
1976	4110	12139	7923	2875	1305	495	140	53	17	21	4	3
1977	935	9156	8326	3209	920	395	265	117	57	43	31	11
1978	502	5146	6096	4006	1753	653	235	178	72	27	17	10
1979	135	3072	10321	5066	2353	721	233	84	53	24	13	10
1980	368	1625	5054	8156	3379	1254	327	114	56	45	21	25
1981	1022	2888	3136	4652	5855	1622	539	175	67	35	18	2
1982	130	5092	4430	2348	2861	2939	640	243	83	30	11	7
1983	760	2682	9174	4080	1752	1150	1041	244	91	37	18	8
1984	203	4521	4538	7018	2221	584	542	338	134	35	8	8
1985	152	2639	8031	5144	5242	1480	626	545	353	109	21	6
1986	306	5103	10253	11228	4283	2167	650	224	171	143	79	23
1987	585	2956	11023	9763	5453	1416	1107	341	149	78	135	50
1988	935	4951	4971	6471	5046	1793	630	284	123	75	53	31
1989	1071	8995	7842	2863	2549	1112	600	223	141	57	29	26
1990	2006	8622	8195	3329	1483	1237	692	350	142	104	47	22
1991	812	7981	10028	5907	2164	807	620	428	108	76	50	22
1992	1422	4159	8424	6538	2266	658	269	192	187	83	34	41
1993	278	3712	2035	3156	1334	401	89	38	52	13	14	5
1994	9	78	173	74	62	28	12	3	2	0	0	0
1995	3	7	56	119	57	37	7	2	0	0	0	0
1996	9	43	43	101	125	35	24	8	2	1	0	0
1997	66	427	1130	497	937	826	187	93	31	4	1	0
1998	91	373	793	1550	948	1314	1217	225	120	56	15	1
1999	49	628	1202	2156	2321	1020	960	873	189	110	21	8
2000	76	335	736	1352	1692	1484	810	530	624	92	37	16
2001	80	475	718	1099	1143	796	674	257	202	192	28	13
2002	155	607	1451	1280	900	722	419	355	96	70	71	14
2003	15	301	879	1810	1139	596	337	277	167	67	55	84
2004	62	113	654	1592	1713	649	266	180	104	47	17	24
2005	49	330	515	1007	1628	1087	499	143	95	41	26	12
2006	43	253	866	928	846	1055	632	237	80	36	19	7
2007	97	311	727	1072	761	501	526	401	160	44	34	21
2008	35	422	617	1105	976	634	350	295	193	91	27	12
2009	17	129	813	1000	902	460	205	99	114	86	56	12
2010	31	377	549	1240	726	385	181	76	22	57	30	8
2011	31	136	839	809	854	351	172	68	33	23	17	8
2012	8	66	183	675	621	396	146	63	23	31	6	11
2013	6	154	431	332	488	361	140	49	22	21	5	9

Table 6a. Mean annual weights-at-age (kg) calculated from lengths-at-age based on samples from commercial fisheries (including food fisheries and sentinel surveys where available) in Subdiv. 3Ps in 1959-2013. The weights-at-age from 1976 are extrapolated back to 1959.

Year	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14
1959	0.280	0.690	1.080	1.680	2.400	3.210	4.100	5.060	6.090	7.200	8.360	9.580
1960	0.280	0.690	1.080	1.680	2.400	3.210	4.100	5.060	6.090	7.200	8.360	9.580
1961	0.280	0.690	1.080	1.680	2.400	3.210	4.100	5.060	6.090	7.200	8.360	9.580
1962	0.280	0.690	1.080	1.680	2.400	3.210	4.100	5.060	6.090	7.200	8.360	9.580
1963	0.280	0.690	1.080	1.680	2.400	3.210	4.100	5.060	6.090	7.200	8.360	9.580
1964	0.280	0.690	1.080	1.680	2.400	3.210	4.100	5.060	6.090	7.200	8.360	9.580
1965	0.280	0.690	1.080	1.680	2.400	3.210	4.100	5.060	6.090	7.200	8.360	9.580
1966	0.280	0.690	1.080	1.680	2.400	3.210	4.100	5.060	6.090	7.200	8.360	9.580
1967	0.280	0.690	1.080	1.680	2.400	3.210	4.100	5.060	6.090	7.200	8.360	9.580
1968	0.280	0.690	1.080	1.680	2.400	3.210	4.100	5.060	6.090	7.200	8.360	9.580
1969	0.280	0.690	1.080	1.680	2.400	3.210	4.100	5.060	6.090	7.200	8.360	9.580
1970	0.280	0.690	1.080	1.680	2.400	3.210	4.100	5.060	6.090	7.200	8.360	9.580
1971	0.280	0.690	1.080	1.680	2.400	3.210	4.100	5.060	6.090	7.200	8.360	9.580
1972	0.280	0.690	1.080	1.680	2.400	3.210	4.100	5.060	6.090	7.200	8.360	9.580
1973	0.280	0.690	1.080	1.680	2.400	3.210	4.100	5.060	6.090	7.200	8.360	9.580
1974	0.280	0.690	1.080	1.680	2.400	3.210	4.100	5.060	6.090	7.200	8.360	9.580
1975	0.280	0.690	1.080	1.680	2.400	3.210	4.100	5.060	6.090	7.200	8.360	9.580
1976	0.280	0.690	1.080	1.680	2.400	3.210	4.100	5.060	6.090	7.200	8.360	9.580
1977	0.550	0.680	1.300	1.860	2.530	3.420	4.190	4.940	5.760	6.760	8.190	10.300
1978	0.450	0.700	1.080	1.750	2.450	2.994	4.100	5.160	5.770	7.200	7.750	8.720
1979	0.410	0.650	1.010	1.650	2.550	3.686	4.300	5.400	7.000	8.200	9.130	11.640
1980	0.520	0.720	1.130	1.990	2.480	3.600	5.400	6.950	7.290	8.540	9.130	9.580
1981	0.480	0.790	1.300	1.800	2.720	4.360	5.660	7.410	8.340	8.760	9.130	9.580
1982	0.450	0.770	1.170	1.780	2.360	3.880	5.810	6.180	8.130	8.540	11.400	11.400
1983	0.580	0.840	1.330	1.990	2.580	3.260	3.770	5.340	6.580	8.430	10.300	11.400
1984	0.660	1.040	1.400	1.970	2.640	3.770	4.750	5.560	6.810	7.340	11.200	11.400
1985	0.630	0.850	1.230	1.790	2.810	3.440	5.020	6.010	6.810	7.180	9.810	11.400
1986	0.540	0.750	1.160	1.640	2.430	3.150	4.300	5.500	6.190	8.720	8.760	11.310
1987	0.560	0.770	1.210	1.630	2.310	3.020	4.330	5.110	6.300	8.540	7.380	8.340
1988	0.630	0.820	1.060	1.670	2.410	2.800	3.580	4.980	5.810	6.630	7.460	8.820
1989	0.630	0.810	1.160	1.630	2.260	3.330	4.110	5.180	6.290	7.200	7.750	8.720
1990	0.580	0.860	1.270	1.850	2.450	3.000	4.220	5.590	6.960	8.200	8.110	10.300
1991	0.600	0.750	1.170	1.740	2.370	3.010	3.690	4.730	6.340	7.660	8.540	9.720
1992	0.459	0.694	1.038	1.560	2.228	2.891	4.142	5.542	6.430	8.220	10.300	11.600
1993	0.355	0.680	1.077	1.480	2.117	2.824	4.341	6.502	6.680	7.494	8.940	8.238
1994	0.617	0.916	1.303	1.860	2.654	3.748	5.193	6.977	8.291	8.758	8.754	8.177
1995	0.520	0.850	1.570	2.030	2.410	3.780	5.460	6.930	8.210	9.150	9.590	9.241
1996	0.674	0.985	1.485	2.048	2.508	3.641	5.232	6.931	8.823	9.686	9.757	9.824
1997	0.617	0.898	1.304	1.871	2.510	3.242	4.411	5.934	6.587	8.365	8.139	10.733
1998	0.620	1.000	1.570	2.050	2.400	3.500	4.580	6.130	6.630	8.210	8.760	8.760
1999	0.700	0.900	1.570	2.310	2.590	3.800	5.110	6.500	6.990	8.210	8.140	8.760
2000	0.615	0.896	1.358	2.066	2.741	3.813	5.162	6.516	8.138	8.123	8.423	7.734
2001	0.689	1.018	1.440	1.935	2.575	3.405	5.208	6.456	8.160	8.862	7.809	8.115
2002	0.572	1.017	1.544	2.040	2.504	3.104	4.538	6.896	8.614	8.340	8.898	7.842
2003	0.681	0.974	1.574	2.111	2.542	3.634	3.867	4.750	6.297	8.130	8.910	10.140
2004	0.567	0.963	1.368	2.036	2.496	3.737	4.851	5.921	6.927	8.324	9.128	8.760
2005	0.637	0.943	1.386	1.840	2.458	3.604	5.161	6.246	6.381	8.153	8.526	8.854
2006	0.567	1.010	1.549	1.939	2.167	3.748	5.435	6.465	8.133	8.423	8.563	8.498
2007	0.556	0.938	1.444	1.962	2.295	3.533	5.772	6.957	8.512	8.881	8.779	8.808
2008	0.663	0.981	1.350	1.910	2.221	3.465	5.628	7.834	8.139	8.762	8.303	8.455
2009	0.626	1.019	1.533	1.932	2.315	3.482	5.614	8.171	8.811	8.735	8.571	8.396
2010	0.635	1.089	1.963	2.009	2.360	3.585	5.781	7.932	8.518	8.411	8.520	8.981
2011	1.060	1.063	1.374	1.633	2.170	3.422	5.717	7.995	8.388	8.836	8.308	8.424
2012	0.772	0.930	1.392	1.948	2.012	3.174	5.469	7.307	8.596	8.514	8.333	8.307
2013	0.628	1.184	1.568	1.860	2.138	2.950	5.569	7.978	8.092	8.252	8.464	8.416

Table 6b. Beginning of the year weights-at-age (kg) calculated from commercial annual mean weights-at-age. The values for 1978 are extrapolated back to 1958.

Year	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14
1958	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1959	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1960	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1961	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1962	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1963	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1964	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1965	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1966	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1967	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1968	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1969	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1970	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1971	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1972	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1973	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1974	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1975	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1976	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1977	4.68	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1978	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1979	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1980	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1981	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1982	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1983	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1984	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1985	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1986	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1987	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1988	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1989	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1990	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1991	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1992	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1993	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1994	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1995	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1996	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1997	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1998	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
1999	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
2000	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
2001	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
2002	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
2003	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
2004	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
2005	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
2006	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
2007	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
2008	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
2009	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
2010	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
2011	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
2012	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
2013	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67
2014	1.78	4.40	6.91	8.34	9.08	9.78	9.98	9.94	9.99	10.47	10.37	10.67

Table 7a. Standardized gillnet (5.5 in mesh) annual catch rate-at-age indices estimated using data from sentinel fishery fixed sites. Catch rates are expressed as fish per net.

Year	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Total
1995	1.02	1.07	1.01	0.46	0.15	0.05	0.06	0.06	3.82
1996	1.01	1.04	1.04	0.67	0.26	0.09	0.03	0.07	4.21
1997	1.01	1.03	1.01	0.63	0.27	0.08	0.02	0.04	4.09
1998	1.00	1.00	1.00	0.60	0.27	0.09	0.02	0.03	3.99
1999	1.00	1.00	1.01	0.59	0.26	0.09	0.02	0.03	3.99
2000	1.01	1.02	1.04	0.65	0.27	0.09	0.02	0.03	4.13
2001	1.01	1.01	1.03	0.65	0.27	0.09	0.02	0.03	4.11
2002	1.00	1.02	1.05	0.72	0.31	0.10	0.02	0.03	4.26
2003	1.01	1.01	1.02	0.66	0.28	0.09	0.02	0.03	4.12
2004	1.00	1.01	1.02	0.67	0.28	0.09	0.02	0.03	4.13
2005	1.00	1.02	1.03	0.69	0.29	0.09	0.02	0.03	4.18
2006	1.00	1.01	1.02	0.67	0.28	0.09	0.02	0.03	4.13
2007	1.00	1.01	1.01	0.66	0.28	0.09	0.02	0.03	4.11
2008	1.00	1.01	1.01	0.64	0.27	0.09	0.02	0.03	4.07
2009	1.01	1.02	1.04	0.69	0.29	0.09	0.02	0.03	4.19
2010	1.01	1.03	1.05	0.72	0.30	0.10	0.02	0.03	4.26
2011	1.01	1.01	1.02	0.67	0.28	0.09	0.02	0.03	4.13
2012	1.00	1.01	1.03	0.67	0.28	0.09	0.02	0.03	4.13
2013	1.01	1.02	1.04	0.68	0.28	0.09	0.02	0.03	4.17
2014	1.01	1.02	1.03	0.67	0.28	0.09	0.02	0.03	4.15

Table 7b. Standardized line-trawl annual catch rate-at-age indices estimated using data from sentinel fishery fixed sites. Catch rates are expressed as fish per 1000 hooks.

Year	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Total
1995	8.87	7.87	45.45	7.24	0.85	0.17	0.02	0.06	150.45
1996	7.76	28.19	27.16	45.47	45.23	1.87	0.18	0.06	175.45
1997	1.34	22.75	24.75	16.34	16.34	25.24	0.83	0.02	116.62
1998	5.43	5.83	16.52	11.60	5.52	3.44	0.49	0.03	85.01
1999	4.68	16.19	23.44	5.25	1.68	0.71	0.24	0.06	76.26
2000	11.82	26.83	24.26	16.42	7.87	3.03	1.1	0.24	97.11
2001	17.23	35.34	22.81	11.48	7.52	4.3	1.23	0.29	97.23
2002	13.59	27.87	25.12	8.78	3.17	1.05	0.31	0.1	94.12
2003	8.44	33.55	34.33	20.31	7.46	2.46	1.1	0.27	108.44
2004	4.28	13.33	16.44	13.39	10.19	3.34	0.82	0.34	61.11
2005	5.11	14.68	13.35	11.48	11.62	4.23	0.87	0.62	71.28
2006	6.67	16.42	26.18	16.67	11.24	4.48	1.11	0.34	101.79
2007	10.42	18.24	15.42	11.45	8.26	3.27	0.42	0.1	76.68
2008	8.34	25.42	33.46	16.48	8.46	3.42	0.75	0.21	97.33
2009	5.12	21.45	27.27	13.14	6.33	1.78	0.34	0.09	75.24
2010	3.11	14.45	11.46	10.23	4.66	2.1	0.79	0.2	54.11
2011	7.43	13.63	17.28	11.27	10.45	3.34	1.1	0.43	64.66
2012	5.1	11.23	13.32	13.17	11.48	4.67	0.45	0.27	64.83
2013	3.12	8.56	7.45	8.33	6.56	2.56	0.67	0.19	46.27
2014	3.43	9.78	12.36	12.34	9.26	4.43	1.17	0.73	65.12

Table 4. Annual number of logbook records from target vessels (< 20 m LOA) in SAPO (Uyeda, IPA) used in the analysis of catch and catch rate by gillnets, trammelnets and other current during 1998 to 2010.

Year	Annual catch records	Unaligned catch records	Aligned catch records	Total catch records	Annual effort records	Unaligned effort records	Aligned effort records	Total effort records
1998	1 134	2 1	457	1634	1 1 4	399	1 0	1 1 5
1999	1 099	2 0	394	1 4 7 5	1 0 1 6	3 0	1 0	1 0 7
2000	1 0 7 1	2 1	397	1 4 7 2	1 0 7 5	3 0	1 0	1 0 8
2001	1 1 1 4	2 0	1 1 7	1 5 3 1	1 0 5 8	3 7	1 1	1 0 7
2002	1 1 0 2	2 1	1 0 8	1 4 1 0	1 0 4 1	3 5	1 0	1 0 6
2003	1 0 1 0	2 1	1 0 4	1 4 1 4	1 0 3 8	3 5	1 0	1 0 7
2004	1 0 1 0	2 1	1 0 5	1 4 0 0	1 0 2	3 7	1 0	1 0 5
2005	1 0 1 0	2 0	1 0 5	1 4 1 7	1 0 1 1	3 6	1 0	1 0 5
2006	1 1 0	2 0	1 0	1 4 1 0	1 0 1	3 6	1 0	1 0 6
2007	1 0 1 1	2 1	1 1	1 4 1 1	1 0 1 5	3 5	1 1	1 0 5
2008	1 1 1	2 1	1 0	1 4 1 4	1 0 1 5	3 7	1 0	1 0 5
2009	1 0 0	2 0	1 0	1 4 0 1	1 0 0	3 5	1 0	1 0 7
2010	1 0 0	2 0	1 0	1 4 1	1 0 1	3 5	1 0	1 0 7
2011	1 0	2	1 0 1	1 4 1	1 0 0	3 5	1 0 1	1 0 7
2012	1 0 1	2 0	1 0	1 4 1	1 0 0	3 5	1 0	1 0 2
2013	1 0 7	2 0	1 0	1 4 0	1 0 0	3 5	1 0	1 0 7
2014	1 1 1	2 0	1 1	1 4 0	1 0 0	3 5	1 1	1 0 1

Table 4b. Annual number of out-tagged ivy (*Hedera helix*) fruits, 2014–2023, with 95% confidence intervals, and estimated number of fruits consumed by each of the two most frequent dispersers.

Year	Fruits out-tagged	95% CI lower	95% CI upper	Consumed by *Turdus merula*	Consumed by *Sylvia atricapilla*
2014	1,842	1,731	1,958	1,104	612
2015	2,310	2,176	2,451	1,389	744
2016	1,967	1,840	2,099	1,172	655
2017	2,655	2,498	2,820	1,601	871
2018	2,488	2,339	2,644	1,498	812
2019	3,104	2,931	3,286	1,866	1,021
2020	2,731	2,572	2,898	1,640	889
2021	2,402	2,259	2,553	1,443	781
2022	2,876	2,711	3,049	1,729	938
2023	2,540	2,391	2,697	1,526	827

Table 4c. Annual number of out-tagged seasonal-forest (*Miombo*) fruits, 2014–2023, with 95% bootstrap confidence intervals, and estimated number consumed by each of the two most frequent dispersers.

Year	Fruits out-tagged	95% CI lower	95% CI upper	Consumed by *Turdus olivaceus*	Consumed by *Cercotrichas barbata*
2014	1,612	1,508	1,721	1,031	548
2015	2,045	1,918	2,178	1,318	702
2016	1,733	1,622	1,851	1,104	589
2017	2,318	2,171	2,472	1,486	791
2018	2,190	2,052	2,335	1,402	748
2019	2,764	2,589	2,948	1,771	944
2020	2,402	2,251	2,561	1,538	819
2021	2,117	1,984	2,257	1,356	722
2022	2,533	2,374	2,701	1,622	864
2023	2,239	2,098	2,388	1,434	763

Table 4d. Harmonic rates nested on tagging for various size groups of fruit tagged in three contrast years of *Myrtus nivalis*, 2014.

Fruit class	Year	4–5 mm	6 mm	7 mm	8 mm	9 mm
4 mm	2014	0.02	0.02	0.04	0.02	0.01
4 mm	2015					
4 mm	2016					
5 mm	2014					
5 mm	2015					
5 mm	2016					
6 mm	2014	0.03	0.03	0.06	0.03	
6 mm	2015	0.04	0.03	0.05	0.03	0.01
6 mm	2016					
7 mm	2014					
7 mm	2015					
7 mm	2016					
8 mm	2014	0.05	0.04	0.07	0.04	0.02
8 mm	2015	0.06	0.04	0.06	0.04	0.01
8 mm	2016	0.05	0.04	0.06	0.04	0.02
9 mm	2014	0.07	0.05	0.08	0.05	0.02
9 mm	2015	0.08	0.06	0.09	0.06	0.03
9 mm	2016	0.07	0.05	0.08	0.05	0.02
10 mm	2014	0.09	0.07	0.10	0.07	0.03
10 mm	2015	0.10	0.07	0.11	0.07	0.03
10 mm	2016	0.09	0.07	0.10	0.07	0.03

Table 10. Details of municipal WTP's treatment capital investigation in 2020.

Code	Municipality	Water Volume	Water Value	Value	Code	Water Loss Volume	Water Loss Value
3500	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3501	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3502	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3503	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3504	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3505	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3506	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3507	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3508	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3509	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3510	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3511	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3512	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3513	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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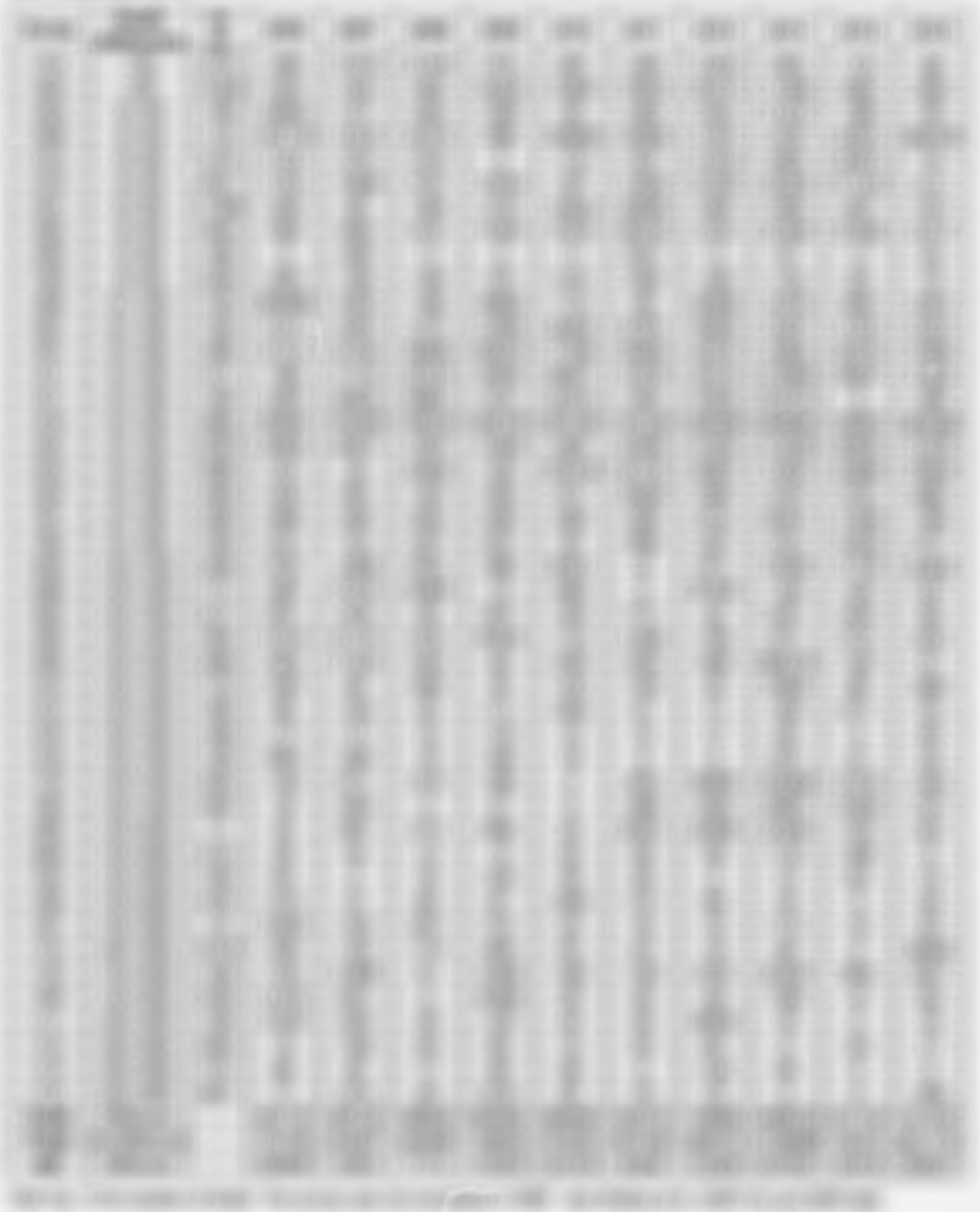


Table 10. Cod biomass estimates (t) from DFO bottom-trawl research vessel surveys in NAFO Division 3Ps.[1]

Site-date	Depth (fathoms)	No. sets	2003	2007	2008	2009	2010	2011	2012	2013	2014	2015
[illegible]	>36	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	>36	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	24-

*Table 13a. Mean numbers per tow at age (1-15 only) in Campelen units for the Canadian research vessel bottom trawl survey of NAFO Subdiv. 3Ps (offshore index strata only).**

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Total
1983	6.42	10.01	6.62	1.14	3.72	1.62	0.48	0.89	1.61	0.75	0.36	0.14	0.06	0.05	0.04	33.81
1984	0.30	5.40	2.33	1.55	0.63	2.11	0.77	0.37	0.46	0.71	0.18	0.15	0.06	0.03	0.00	15.03
1985	0.38	7.74	14.89	12.57	9.96	3.28	2.66	0.79	0.48	0.42	0.42	0.49	0.21	0.12	0.03	54.43
1986	0.20	6.62	5.05	6.48	7.96	6.33	2.13	1.47	0.84	0.29	0.24	0.29	0.17	0.10	0.06	38.82
1987	1.09	9.48	5.67	4.97	13.82	8.31	3.35	1.29	0.69	0.28	0.23	0.16	0.17	0.16	0.06	49.73
1988	0.42	9.13	5.93	2.96	2.84	6.50	5.84	3.65	1.49	0.84	0.74	0.35	0.16	0.15	0.09	41.09
1989	0.43	6.50	4.95	3.17	1.51	1.16	2.15	1.21	0.67	0.37	0.41	0.13	0.11	0.05	0.09	22.66
1990	0.09	1.48	9.82	14.49	10.89	5.67	3.84	3.14	1.15	0.71	0.32	0.16	0.12	0.09	0.01	51.88
1991	1.30	27.69	5.03	10.08	11.24	5.75	2.84	1.58	1.19	0.74	0.56	0.22	0.11	0.07	0.04	68.36
1992	0.09	1.80	6.95	2.11	4.15	2.03	1.03	0.53	0.26	0.24	0.08	0.04	0.01	0.01	0.02	19.26
1993 (Feb)	0.09	0.09	1.83	4.03	0.71	2.86	0.68	0.33	0.13	0.09	0.11	0.03	0.04	0.01	0.01	10.96
1993 (Sept)	0.09	0.09	1.89	4.04	1.49	1.35	0.47	0.10	0.04	0.03	0.04	0.01	0.00	0.01	0.01	9.58
1994	0.09	1.63	1.46	4.31	6.10	1.73	1.62	0.50	0.08	0.04	0.03	0.02	0.01	0.01	0.00	17.54
1995	0.09	0.31	1.16	1.67	13.08	19.95	4.40	5.75	2.19	0.25	0.20	0.01	0.07	0.03	0.00	48.77
1996	0.09	1.08	3.67	3.62	1.32	2.69	2.91	0.54	0.46	0.09	0.09	0.02	0.00	0.00	0.00	17.39
1997	0.22	1.53	2.33	1.04	0.50	0.26	0.30	0.24	0.14	0.05	0.02	0.00	0.00	0.00	0.00	6.65
1998	0.52	0.97	6.79	8.42	5.60	3.89	1.96	2.50	2.79	0.43	0.30	0.06	0.03	0.00	0.00	34.36
1999	1.24	2.54	2.55	2.38	2.58	2.34	1.72	0.44	0.79	0.60	0.09	0.02	0.02	0.00	0.00	17.31
2000	1.25	3.33	5.36	3.10	2.17	1.82	1.20	0.89	0.35	0.31	0.53	0.12	0.00	0.01	0.00	20.44
2001	0.57	2.25	12.41	12.29	4.36	2.04	1.25	0.77	0.71	0.38	0.50	0.94	0.12	0.05	0.03	38.70
2002	0.58	1.10	3.90	8.28	5.85	3.04	2.04	0.89	0.53	0.37	0.08	0.12	0.19	0.01	0.00	27.08
2003	0.52	1.46	1.78	4.08	6.55	3.94	1.50	0.72	0.33	0.18	0.19	0.05	0.11	0.01	0.01	21.43
2004	0.30	1.30	2.07	1.71	2.08	4.05	4.24	1.35	0.81	0.67	0.79	0.15	0.10	0.02	0.07	20.12
2005	0.77	1.43	5.73	4.95	1.60	0.89	0.79	0.71	0.28	0.05	0.17	0.08	0.03	0.03	0.09	18.61
2006	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
2007	3.18	1.73	4.64	3.11	1.48	0.76	0.44	0.22	0.47	0.42	0.12	0.09	0.08	0.05	0.01	17.00
2008	0.47	4.39	4.51	3.32	1.92	1.12	0.47	0.32	0.12	0.15	0.10	0.04	0.03	0.01	0.00	16.97
2009	0.40	1.43	9.25	6.67	5.70	3.09	1.79	0.99	0.21	0.17	0.21	0.38	0.14	0.02	0.00	30.45
2010	0.60	2.13	7.65	15.71	6.70	4.06	1.47	0.29	0.10	0.04	0.04	0.09	0.01	0.00	0.00	38.89
2011	0.10	4.70	6.55	2.46	5.08	1.92	1.41	0.48	0.10	0.09	0.00	0.02	0.01	0.01	0.00	22.97
2012	5.92	2.54	8.68	5.82	3.22	3.38	1.75	0.96	0.17	0.35	0.02	0.04	0.00	0.01	0.02	32.79
2013	1.58	16.42	11.49	16.61	6.43	4.50	3.09	2.36	0.56	0.28	0.07	0.01	0.00	0.01	0.00	65.41
2014	0.85	3.33	11.33	4.74	2.22	1.15	0.43	0.94	0.48	0.07	0.00	0.01	0.00	0.01	0.00	25.56
2015	0.11	4.55	9.11	12.60	3.32	1.36	1.07	0.36	0.50	0.06	0.01	0.00	0.00	0.00	0.00	33.05

*Data are adjusted for missing strata. The survey in 2006 was not completed and there were two surveys in 1993 (February and April).

Table 13b. Mean numbers per tow at age (1-15 only) in Campelen units for the Canadian research vessel bottom trawl survey of NAFO Subdiv. 3Ps (inshore and offshore strata).

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15	Total
1997	0.32	1.68	2.44	1.01	0.46	0.25	0.26	0.21	0.12	0.04	0.01	0.00	0.00	0.00	0.00	6.80
1998	0.72	1.28	6.28	7.40	4.91	3.53	1.73	2.19	2.43	0.38	0.26	0.06	0.03	0.00	0.00	31.20
1999	1.31	3.05	2.52	2.26	2.41	2.12	1.54	0.39	0.68	0.52	0.07	0.02	0.02	0.01	0.00	16.92
2000	1.38	3.84	6.66	3.52	2.24	1.75	1.11	0.80	0.31	0.28	0.46	0.11	0.00	0.01	0.00	22.47
2001	0.99	2.88	11.44	10.58	3.71	1.74	1.08	0.66	0.60	0.32	0.43	0.80	0.10	0.05	0.03	35.41
2002	0.79	1.53	3.72	7.08	4.95	2.58	1.73	0.85	0.45	0.31	0.07	0.11	0.16	0.01	0.00	24.34
2003	0.61	2.62	2.24	3.67	5.88	3.51	1.34	0.63	0.28	0.16	0.17	0.04	0.09	0.01	0.01	21.26
2004	0.33	2.24	2.50	1.85	1.93	3.49	3.61	1.08	0.68	0.57	0.67	0.13	0.09	0.02	0.06	19.25
2005	0.80	1.63	7.32	7.27	3.49	2.08	1.52	1.20	0.41	0.09	0.15	0.06	0.03	0.03	0.08	26.16
2006	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2007	3.31	2.34	5.33	3.26	2.11	1.14	0.76	0.35	0.56	0.37	0.12	0.10	0.07	0.04	0.01	19.87
2008	0.55	4.09	4.30	3.27	1.99	1.22	0.50	0.34	0.12	0.14	0.08	0.04	0.02	0.01	0.00	16.67
2009	1.44	2.47	8.64	5.81	4.91	2.65	1.53	0.84	0.18	0.15	0.18	0.32	0.12	0.01	0.00	29.25
2010	0.68	2.76	7.75	13.95	5.87	3.53	1.27	0.25	0.08	0.03	0.03	0.07	0.01	0.00	0.00	36.28
2011	0.19	4.63	6.37	2.56	5.46	2.04	1.42	0.49	0.09	0.08	0.00	0.02	0.01	0.01	0.00	23.37
2012	5.50	3.99	11.21	6.37	3.34	3.39	1.76	0.94	0.16	0.25	0.01	0.04	0.00	0.01	0.02	36.99
2013	3.14	19.94	12.11	16.14	5.83	4.04	2.72	2.06	0.48	0.24	0.06	0.01	0.00	0.01	0.00	66.78
2014	1.44	5.21	11.03	4.54	2.23	1.11	0.41	0.83	0.42	0.06	0.00	0.01	0.00	0.01	0.00	27.32
2015	0.41	4.90	8.47	10.97	2.87	1.17	0.92	0.31	0.43	0.06	0.01	0.00	0.00	0.00	0.00	33.05

*Data are adjusted for missing strata. The survey in 2006 was not completed

Table 14. Mean length-at-age (cm) of cod sampled during research bottom-trawl surveys in Subdiv. 3Ps in winter-spring 1983-2015. Shaded entries (*) are based on fewer than 5 aged fish.

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12
1983	10.3	20.2	31.2	43.1	52.9	57.8	65.6	71.5	73.4	79.4	89.6	93.7
1984	12.0*	19.2	30.7	42.1	52.2	60.7	66.2	70.6	75.5	79.1	84.2	98.1
1985	-	17.9	29.1	40.3	51.2	60.2	66.4	74.2	73.9	79.4	88.9	93.0
1986	11.0*	18.8	27.1	40.3	49.0	55.7	62.1	72.2	76.4	82.8	93.3	93.9
1987	10.7	19.9	29.5	39.5	48.4	54.1	61.2	67.3	77.8	85.4	83.2	89.9
1988	9.2*	19.7	29.0	40.7	47.8	56.2	62.2	66.7	74.6	79.7	79.7	87.5
1989	12.0*	19.2	30.2	41.7	48.2	56.3	64.0	71.8	75.9	84.6	88.5	96.6
1990	-	19.9	29.9	40.1	48.3	53.7	56.6	62.3	70.1	76.2	79.1	88.7
1991	9.5	19.2	29.8	39.0	47.0	53.5	57.4	62.8	68.2	73.7	73.8	77.1
1992	-	20.7	30.4	40.9	47.4	55.3	61.2	62.4	66.7	73.3	83.9	81.8
1993	-	-	30.9	41.3	48.0	52.7	62.3	70.6	77.1	80.2*	96.0	106.0*
1994	-	19.1	32.2	39.4	48.2	50.2	53.7	59.1	68.0	87.7	79.7*	90.5
1995	-	21.2*	29.9	42.0	50.4	56.5	58.2	57.9	63.0	79.6	81.3	83.6*
1996	12.6	20.8	30.0	38.7	44.2	52.9	60.9	61.2	63.3	76.8	74.7	86.1*
1997	12.7	24.1	31.8	40.9	48.2	51.6	60.7	65.4	67.3	67.3	82.5*	-
1998	10.6	22.3	32.8	42.7	49.1	53.3	57.6	67.1	77.4	77.2	64.3	78.0*
1999	12.0	22.4	31.4	43.2	51.4	58.9	61.7	66.2	77.6	86.8	76.9	109.0*
2000	13.3	22.0	31.7	40.8	48.8	54.7	60.5	65.3	67.9	81.2	92.7	89.1
2001	10.6	21.9	33.2	40.6	47.6	51.4	57.4	68.8	77.5	75.0	85.5	96.8
2002	12.0	22.0	31.8	42.0	50.8	55.1	55.2	67.2	74.6	79.8	73.4*	86.0
2003	10.7	23.7	31.9	43.0	51.8	55.4	58.6	58.7	70.5	72.0	65.5	86.6*
2004	14.0	20.2	33.7	38.9	47.6	60.8	66.3	69.2	67.3	69.6	73.2	73.5*
2005	12.1	25.5	34.2	41.9	48.6	54.5	63.5	67.6	72.3	72.6*	99.2	103.4
2006	-	-	-	-	-	-	-	-	-	-	-	-
2007	11.1	21.2	30.7	38.1	48.9	54.9	55.8	64.9	81.7	91.6	86.9	86.6
2008	11.7	18.4	26.6	38.5	45.9	53.0	60.2	59.4	66.9	68.2	90.0	94.1
2009	12.3	19.1	31.3	38.7	46.7	55.0	60.5	63.5	72.3	76.0	83.3	87.2
2010	11.8	22.7	30.5	40.4	45.6	55.0	65.8	70.9	75.2	81.1*	92.6*	103.1
2011	14.0	23.5	30.2	40.1	47.1	49.5	56.1	61.7	73.8	53.2*	-	75.5*
2012	11.1	18.6	34.2	41.7	48.1	55.8	53.9	61.0	72.2	73.8*	105.0*	107.0*
2013	12.3	20.4	27.9	41.9	47.7	47.8	53.4	54.0	63.7	55.4	97.0*	95.9*
2014	10.6	20.9	30.2	35.0	47.8	53.4	54.5	63.2	65.0	59.3*	-	80.0*
2015	11.9	20.9	30.5	39.8	45.0	53.8	56.5	56.0	64.5	72.4*	87.0*	-

Table 15. Mean round weight-at-age (kg) of cod sampled during DFO bottom-trawl surveys in Subdiv. 3Ps in winter-spring 1983-2015. Shaded entries (*) are based on fewer than 5 aged fish.

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12
1983	0.01	0.07	0.22	0.66	1.29	1.59	2.15	3.44	3.87	5.22	8.81	10.34
1984	-	0.07	0.25	0.63	1.13	1.84	2.74	3.84	4.26	5.06	8.09	10.03
1985	-	-	0.21	0.49	1.05	1.60	2.30	3.19	3.31*	3.76*	-	3.97*
1986	-	0.05	0.17	0.45	0.87	1.36	2.39	3.25	5.42	4.41	6.42*	9.16
1987	-	-	0.23	0.52	0.92	1.32	1.88	2.41	4.33	6.35	6.74	6.11
1988	-	0.06	0.19	0.56	0.88	1.42	2.17	2.51	4.08	4.77	4.21	9.43
1989	-	0.06	0.24	0.58	0.91	1.28	2.25	3.74	4.57	5.95	8.78	8.88
1990	-	0.06	0.20	0.52	0.96	1.36	1.62	2.19	3.21	4.33	5.09	7.46
1991	0.01	0.05	0.20	0.45	0.84	1.33	1.74	2.37	3.09	4.08	4.10	5.09
1992	-	0.06	0.22	0.54	0.89	1.44	2.06	2.32	2.91	4.15	5.90	5.81
1993	-	-	0.21	0.54	0.86	1.20	2.05	3.13	4.48	4.47*	8.53	13.20*
1994	-	0.05	0.23	0.44	0.87	1.08	1.33	1.87	3.03	6.35	5.21*	7.47
1995	-	0.06*	0.20	0.52	0.93	1.50	1.75	1.75	2.28	4.88	5.50	6.49*
1996	0.02	0.07	0.22	0.46	0.71	1.21	2.04	2.19	2.41	4.46	3.99	7.01*
1997	0.02	0.11	0.26	0.54	0.88	1.15	1.87	2.64	3.06	3.22	5.46*	-
1998	0.01	0.09	0.28	0.62	0.99	1.27	1.63	2.74*	4.76	5.07	2.68	5.25*
1999	0.01	0.10	0.28	0.64	1.10	1.72	2.08	2.57	4.39	6.87	5.12	13.16*
2000	0.02	0.08	0.27	0.57	0.92	1.35	1.90	2.51	2.91	5.19	8.34	8.13
2001	0.01	0.08	0.28	0.55	0.87	1.16	1.67	2.96	4.39	4.35	6.09	9.05
2002	0.01	0.09	0.24	0.56	1.01	1.39	1.45	2.75	4.00	5.11	4.20*	6.24
2003	0.01	0.10	0.27	0.61	1.10	1.46	1.83	1.74	3.15	3.76	2.64	6.56*
2004	0.02	0.07	0.31	0.50	0.86	1.81	2.47	3.15	2.95	3.34	4.25	4.71*
2005	0.01	0.14	0.34	0.62	1.00	1.37	2.24	3.12	4.06	4.47*	10.31	11.30
2006	-	-	-	-	-	-	-	-	-	-	-	-
2007	0.01	0.08	0.23	0.46	0.95	1.44	1.57	2.54	5.34	8.17	7.66	7.82
2008	0.01	0.05	0.16	0.47	0.80	1.18	1.85	1.88	2.78	3.29	7.21	9.11
2009	0.01	0.05	0.24	0.47	0.79	1.39	1.96	2.42	3.68	4.27	6.26	7.07
2010	0.01	0.09	0.22	0.52	0.79	1.40	2.51	3.24	4.24	6.96*	9.05*	11.31
2011	0.02	0.11	0.24	0.50	0.87	1.09	1.67	2.35	3.80	1.30*	-	4.43*
2012	0.01	0.05	0.33	0.60	0.89	1.45	1.35	2.20	3.82	4.02	9.23*	12.61*
2013	0.02	0.07	0.19	0.60	0.89	0.98	1.42	1.43	2.44	1.76	9.88	10.32*
2014	0.01	0.08	0.21	0.35	0.86	1.28	1.36	2.24	2.65*	2.20*	-	4.68
2015	0.01	0.07	0.22	0.49	0.77	1.34	1.58	1.56	2.65	4.02*	5.67*	-

Table 16. Parameter estimates and SE's for a probit model fitted to observed proportions mature at age (from 'combined' survey area) for female cod from NAFO Subdiv. 3Ps based on surveys conducted during 1959-2014.

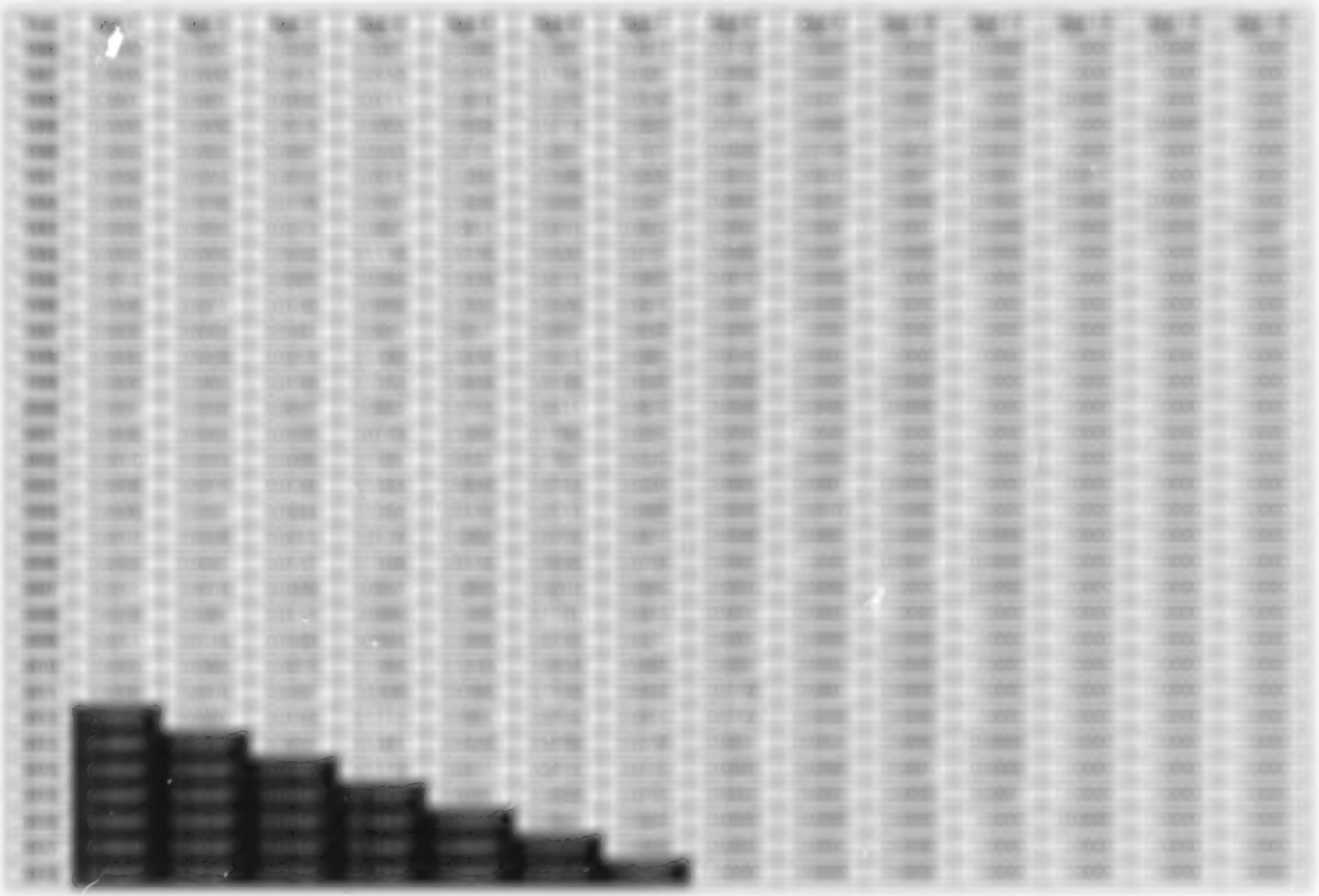
Cohort	Slope	Slope SE	Intercept	Intercept SE	Cohort	Slope	Slope SE	Intercept	Intercept SE
1954	1.1094	0.2940	-8.1702	2.4445	**1983**	1.80##	0.3638	-11.8863	1.4046
1955	1.5059	0.2237	-10.2633	1.6124	**1984**	2.2315	0.3981	-13.4166	1.8244
1956	1.3174	0.3208	-9.4592	2.2216	**1985**	2.6989	0.3726	-16.0342	2.2513
1957	1.4804	0.3703	-10.3248	2.3535	**1986**	2.5639	0.3930	-14.9673	1.9284
1958	2.3929	0.5853	-16.4519	3.6202	**1987**	2.3536	0.2231	-11.6227	1.2850
1959	2.1113	0.5358	-13.0196	2.9364	**1988**	2.7731	0.4110	-14.5212	1.1477
1960	1.6741	0.2990	-10.6677	1.7584	**1989**	1.6646	0.1577	-8.7844	0.8113
1961	1.8639	0.3551	-11.4722	2.0959	**1990**	1.7688	0.1808	-9.2101	0.9575
1962	1.7141	0.2898	-10.5115	1.7043	**1991**	2.4874	0.4871	-13.1443	1.5818
1963*	-	-	-	-	**1992**	2.6215	0.3903	-13.9308	1.6126
1964	1.9272	0.2411	-12.7182	1.5667	**1993**	1.8954	0.2394	-9.9598	1.2967
1965	2.4194	0.5982	-16.4244	4.2387	**1994**	1.8215	0.1969	-9.1481	1.0391
1966	1.5492	0.2401	-10.0808	1.6035	**1995**	1.8523	0.2188	-9.7711	1.1242
1967	1.6876	0.3792	-10.0845	2.3543	**1996**	1.7414	0.2410	-9.3481	1.3535
1968	2.1307	0.2885	-13.1635	1.7869	**1997**	3.0797	0.4567	-14.8452	2.1742
1969	1.6825	0.3043	-10.3672	1.8439	**1998**	1.8884	0.2306	-9.6586	1.1787
1970	1.5265	0.2305	-8.8508	1.3136	**1999**	1.8423	0.2647	-9.1485	1.3155
1971	1.3122	0.1401	-7.8435	0.8346	**2000**	1.7830	0.3025	-8.2716	1.4585
1972	1.4117	0.1445	-8.9091	0.8853	**2001**	1.7588	0.2262	-8.3449	1.0333
1973	1.4521	0.1667	-9.3550	1.0330	**2002**	1.6788	0.2439	-8.9522	1.2645
1974	2.0042	0.1969	-13.1541	1.2844	**2003**	1.5873	0.2363	-8.0379	1.2856
1975	1.7846	0.2174	-11.1641	1.3757	**2004**	1.4098	0.1654	-8.3639	0.9173
1976	1.3952	0.2056	-8.5990	1.2610	**2005**	1.8574	0.2314	-10.0368	1.2524
1977	2.5066	0.3505	-15.3640	2.1732	**2006**	1.7491	0.1791	-8.5921	0.8751
1978	1.7800	0.1680	-10.7323	1.0208	**2007**	1.5798	0.2523	-7.7185	1.1852
1979	1.0297	0.1138	-6.4477	0.7670	**2008**	1.6777	0.2542	-8.3635	1.1113
1980	1.4270	0.1415	-8.4134	0.9131	**2009**	2.3962	0.3272	-10.9313	1.3912
1981	1.7431	0.1781	-11.9865	1.1646	**2010**	3.5736	0.8224	-16.3087	3.7356
1982	2.0091	0.2059	-13.3056	1.3496	-	-	-	-	-

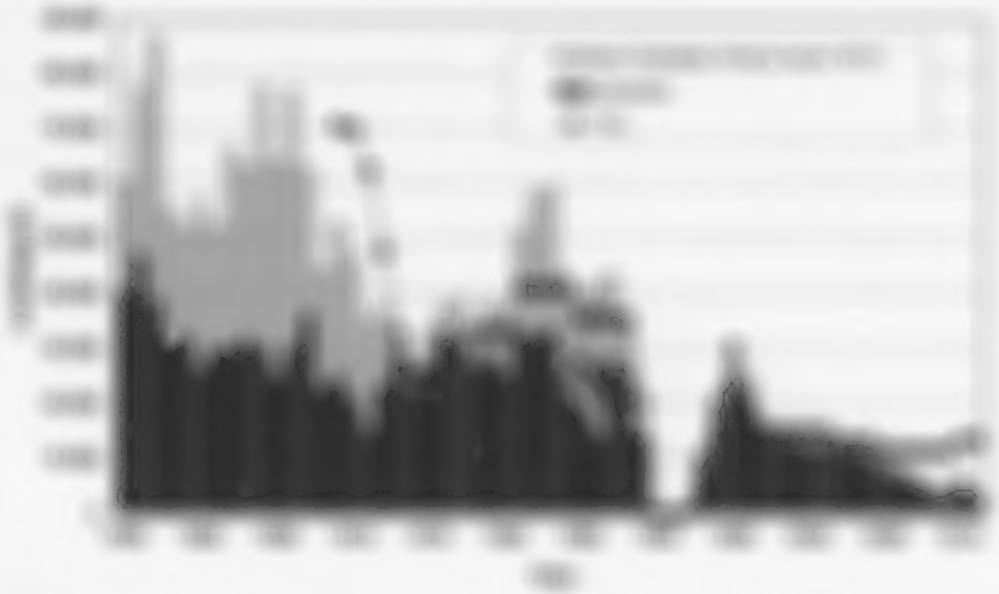
*Fit not significant

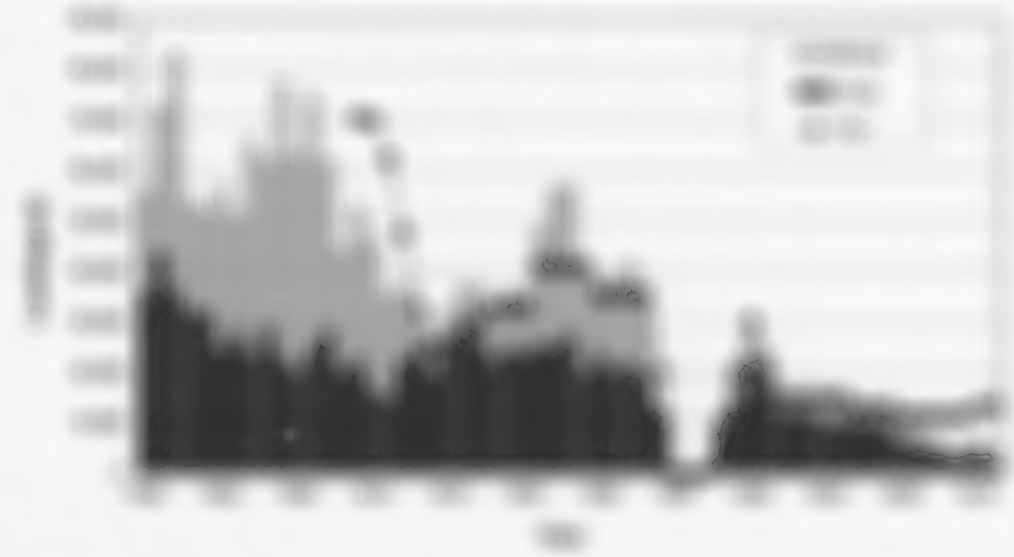
Table 17. Estimated proportions mature for female cod from NAFO Subdiv. 3Ps from (4T) surveys from 1970 to 2015, projected forward to 2018. Estimates were obtained from a probit model fitted by cohort to observed proportions mature at age (from "combined" survey area). Black shaded cells(*) are averages of the three closest cohorts; grey shaded cells (') are the average of estimates for the adjacent cohorts.

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14
1970	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1971	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1972	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1973	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1974	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1975	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1976	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1977	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1978	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1979	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1980	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1981	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1982	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1983	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1984	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1985	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1986	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1987	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1988	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1989	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1990	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1991	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1992	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1993	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1994	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1995	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1996	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1997	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1998	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1999	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2001	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2003	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2004	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2005	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2006	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2007	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2008	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2009	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2010	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2011	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2012	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2013	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2014	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2015	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2016	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2017	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2018	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table VI (Continued)







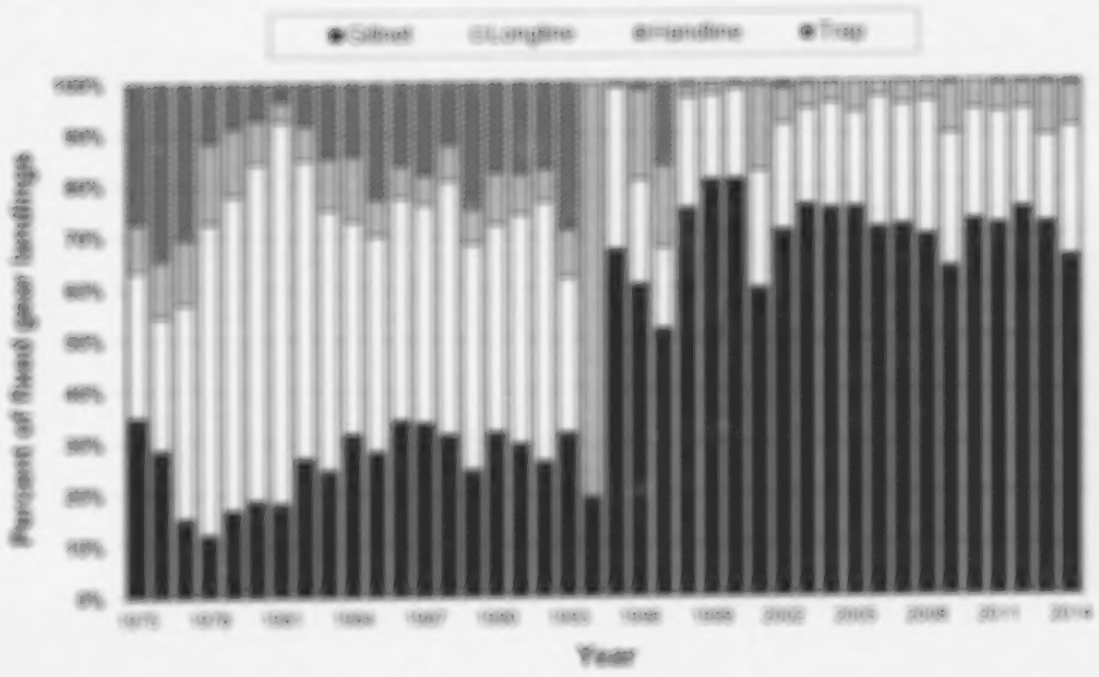


Figure 4. Percent of total fixed gear landings by the four main fixed gears used in the cod fishery in NAFO Subdiv. 3Pn during 1975-2013. The fishery was under a moratorium during 1994-95 and values for these years are based on sentinel and by-catch landings of < 800 t.

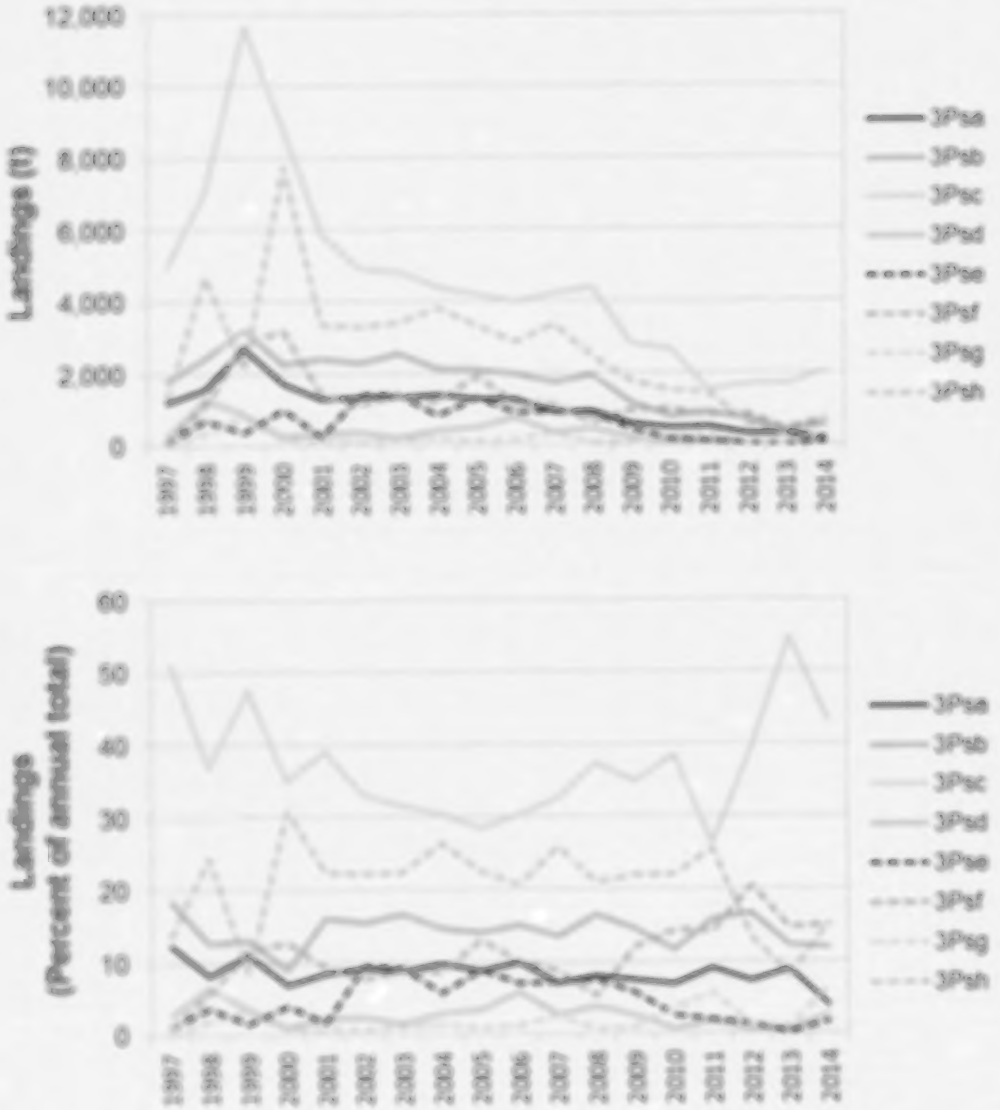


Figure 5. Annual reported landings of cod (upper panel) and percent of annual total (lower panel) by unit area from NAFO Subdiv. 3Ps during 1997-2013. Refer to Figure 1 for locations of unit areas.

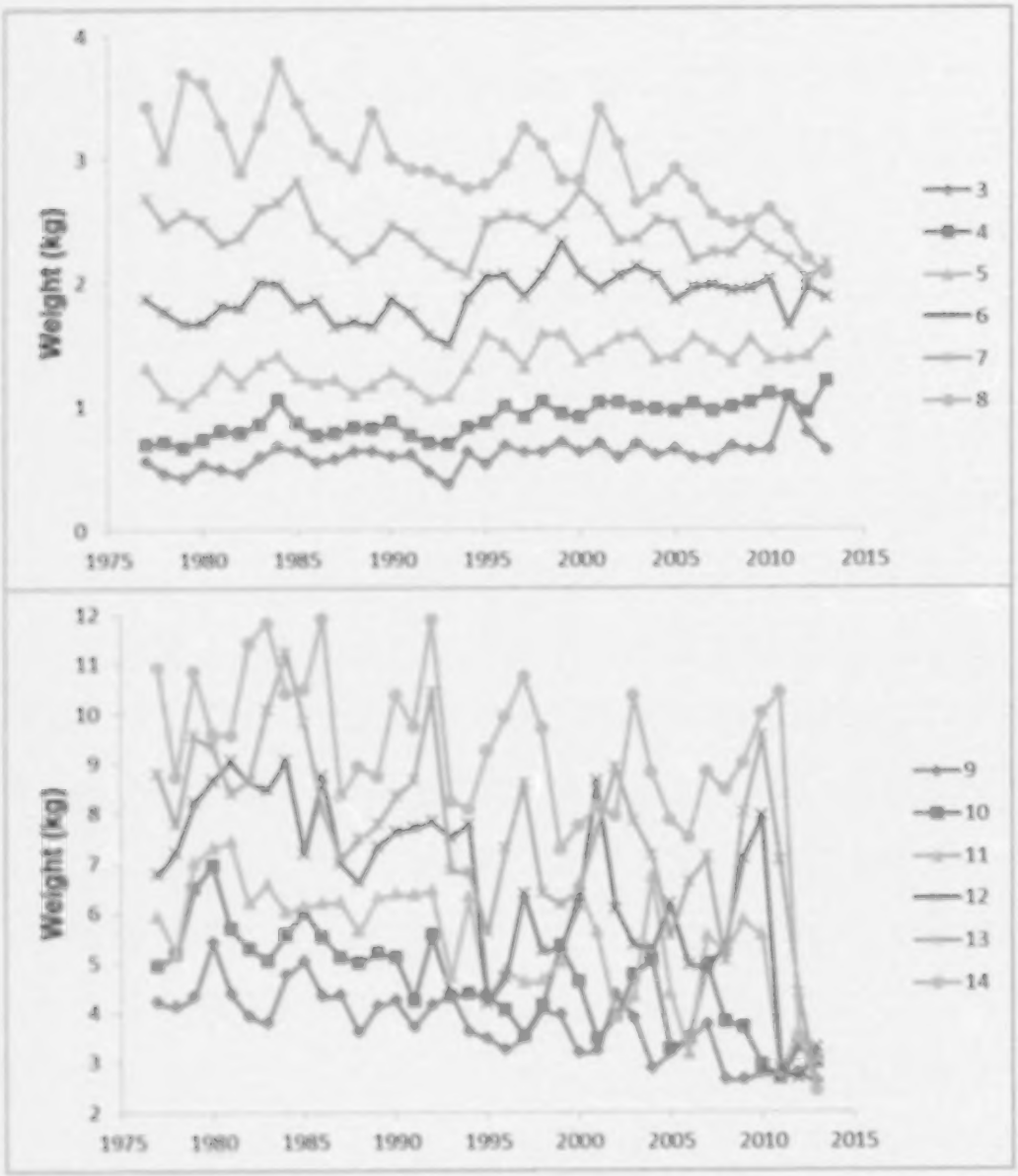


Figure 6. Mean weights-at-age calculated from mean lengths-at-age (upper panel: ages 3-8; lower panel: ages 9-14) from the commercial catch of cod in Subdiv. 3Ps during 1977 to 2013.

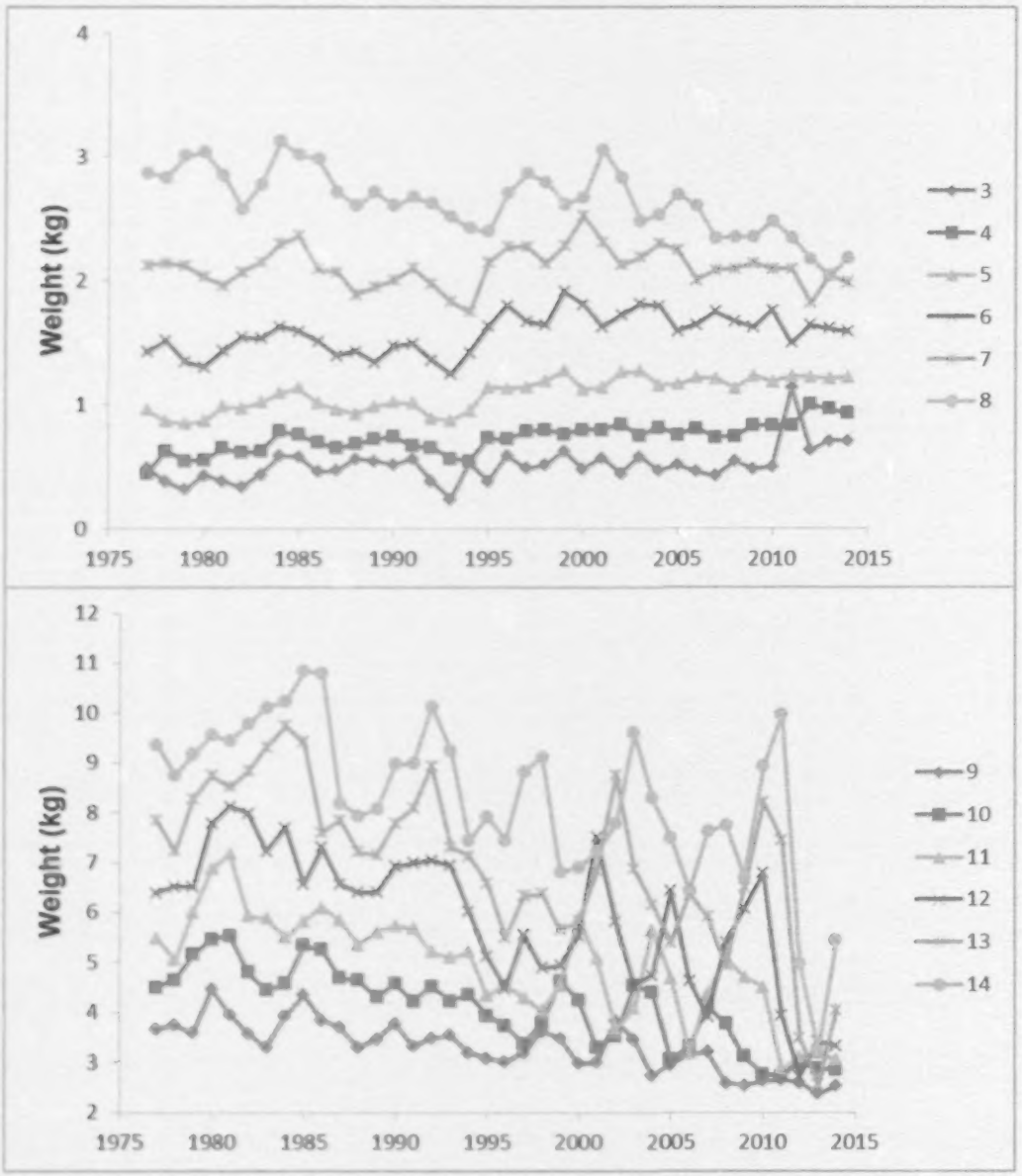


Figure 7. Beginning of year mean weights-at-age (upper panel: ages 3-8; lower panel: ages 9-14) from the commercial catch of cod in Subdiv. 3Ps during 1997 to 2014. Weights at age in 2014 are the geometric means of the prior three years.

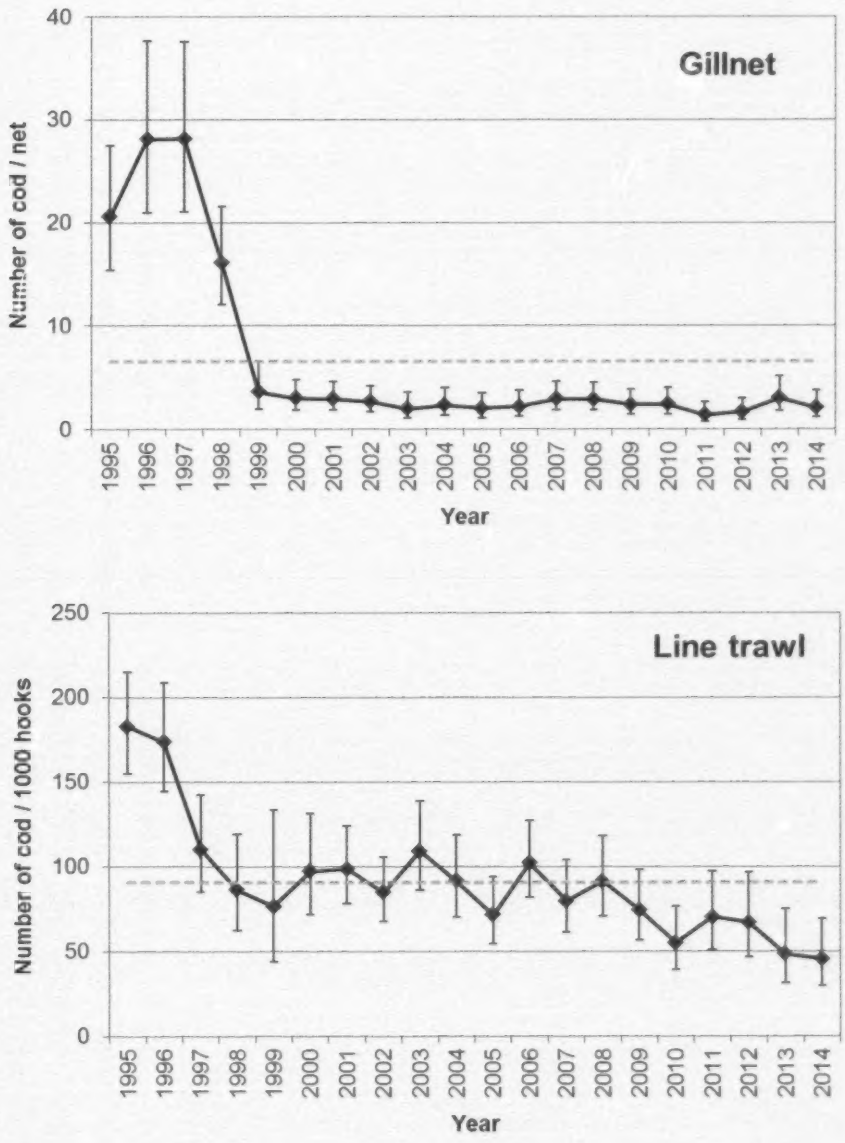


Figure 8a. Standardized age-aggregated catch rate indices for gillnets (5.5" mesh) and line-trawls (with 95% CL's) estimated using data from sentinel fishery fixed sites. Dashed horizontal lines indicate time-series average.

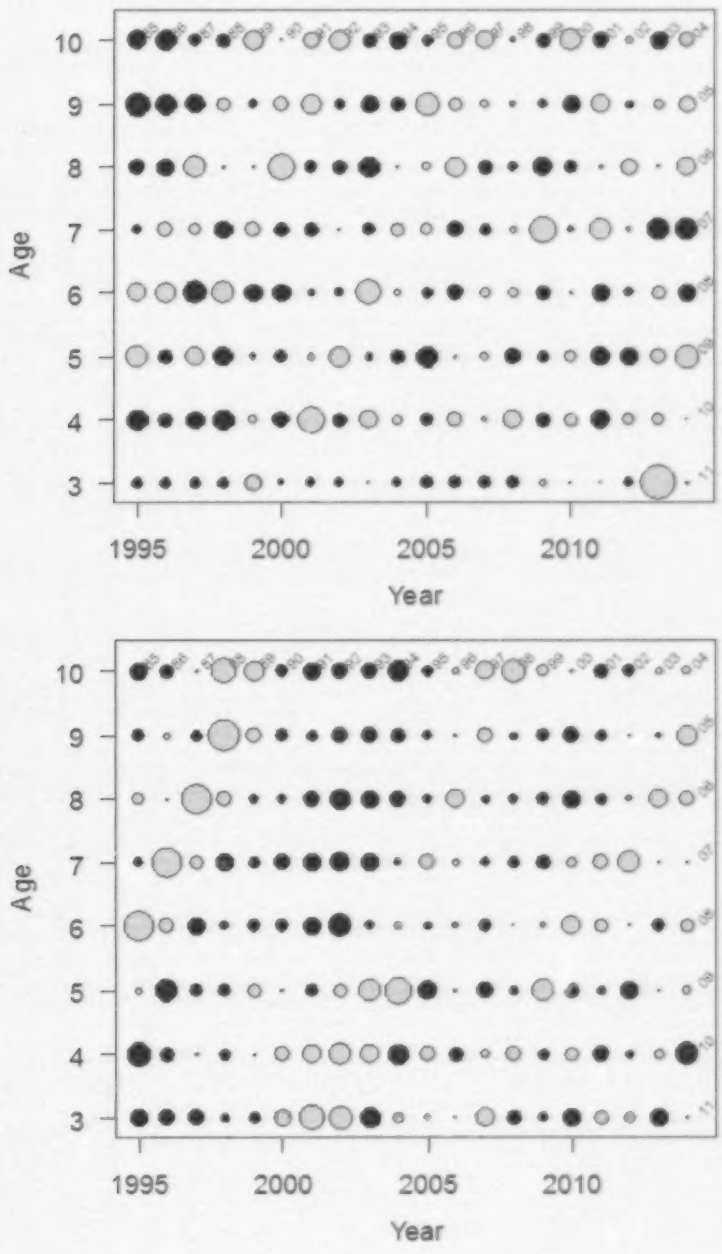


Figure 8b. Standardized proportions at age of sentinel catch rates at age for gillnet (top) and linetrawl (bottom) in Subdiv. 3Ps. Annual proportions were computed, and then standardized by subtracting the mean proportion and dividing by the standard deviation of the proportions across years. Symbol sizes are scaled and values greater than average are shown as grey circles, average values are shown as small dots, and less than average values are shown as black circles. Labels in the upper and right margins identify cohorts.

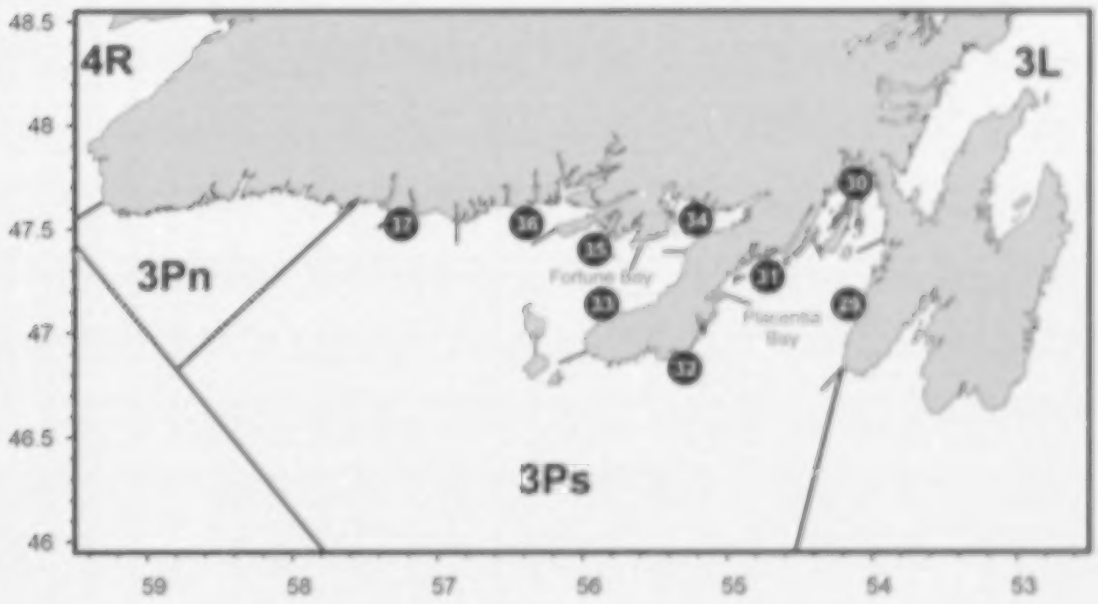


Figure 9a. Location and boundaries of numbered management areas along the inshore of the south coast of Newfoundland (NAFO Subdiv. 3Ps) (29=Placentia Bay East, 30=Head of Placentia Bay, 31=Placentia Bay West, 32=The Boot, 33=Fortune Bay, 34=Head of Fortune Bay, 35=Connaigre, 36=Hermitage Bay, 37=Francois-Burgeo).

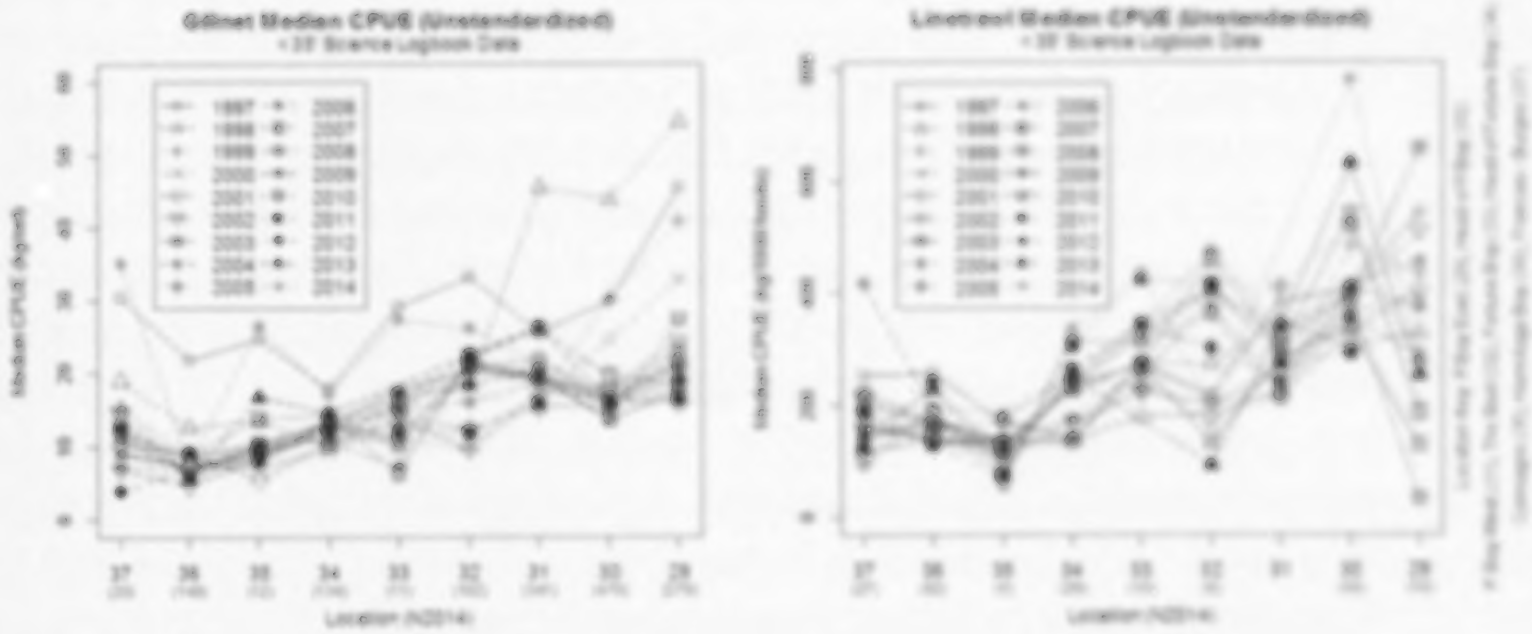

Gillnet Median CPUE (Unstandardized)
< 35' Science Logbook Data
Lobstercat Median CPUE (Unstandardized)
< 35' Science Logbook Data

Figure 6b. Area-specific median annual catch rates of cod from gillnets (left panel, kg per net) and line-trawls (right panel, kg per 1,000 hooks) from science log-books for vessels < 35 ft. Labels on x-axis are lobster fishing areas ordered from west to east (see key on far right). Values in parenthesis on x-axis are number of valid sets per site during the 2013 fishery.

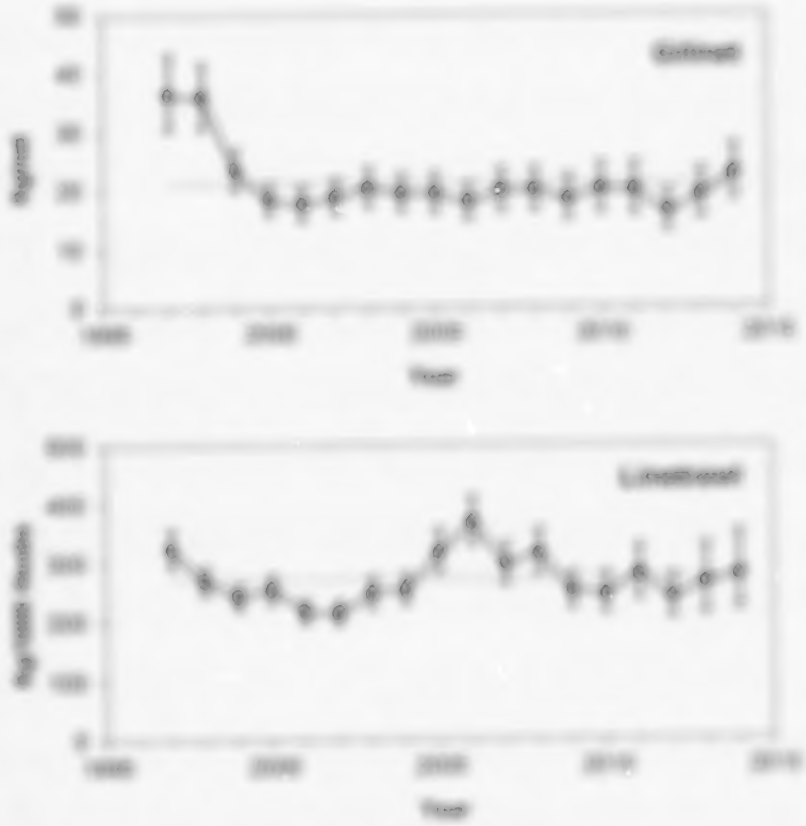


Figure 4x. Standardised catch rates for gillnets and line vessels from science log-books for vessels > 30 ft. Horizontal dashed lines are time-series average, error bars are 95% confidence intervals of the means. Catch rates are expressed in terms of weight (kg per net or kg per 1000 hooks).

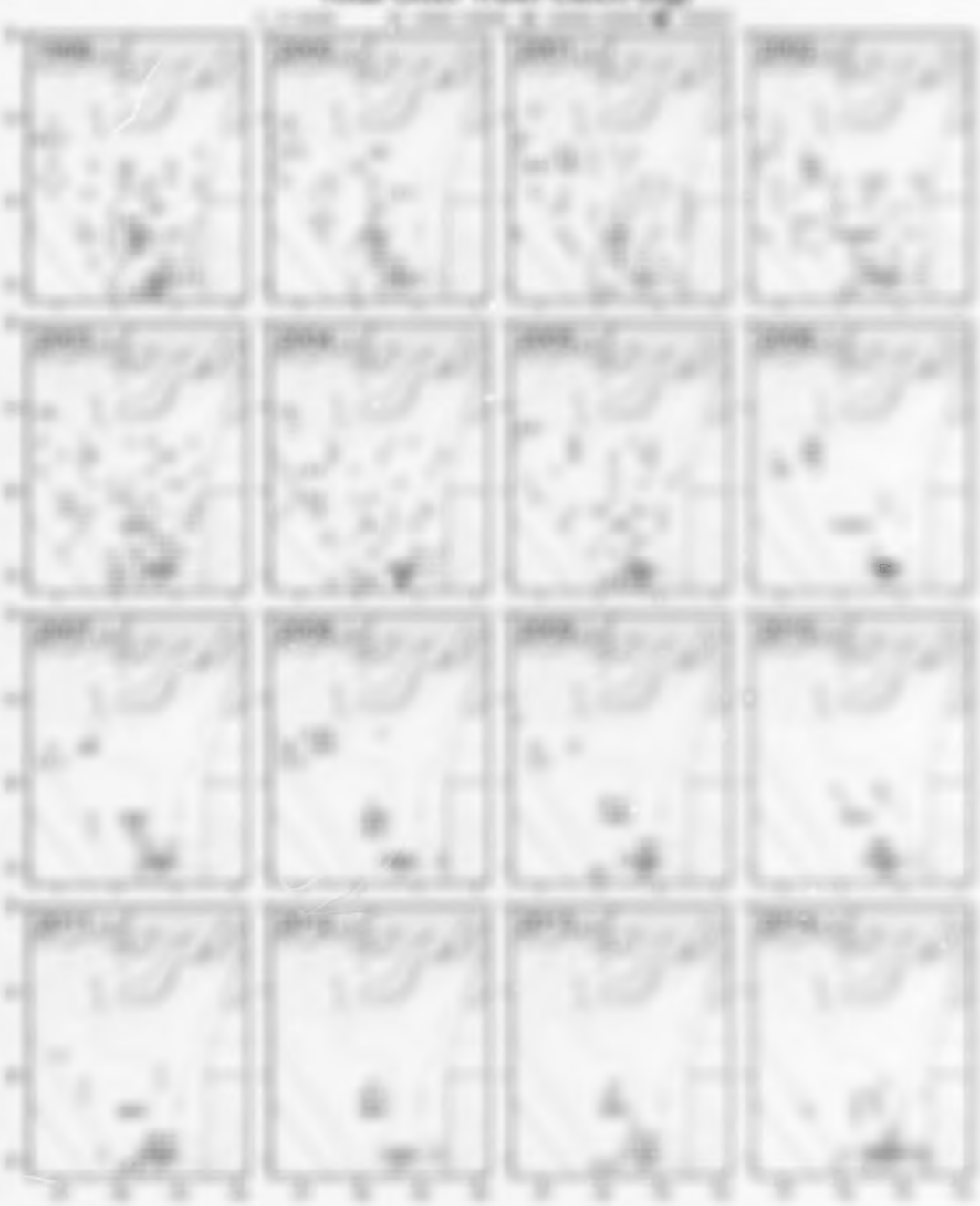


Figure 18b. Otter trawl landings of SPK Cod for 16 by 16 cascade blocks of latitude and longitude as recorded in logbooks from the 48 X Shell survey, 1998 to 2014. Total landings are shown as four colors corresponding to four landings categories.

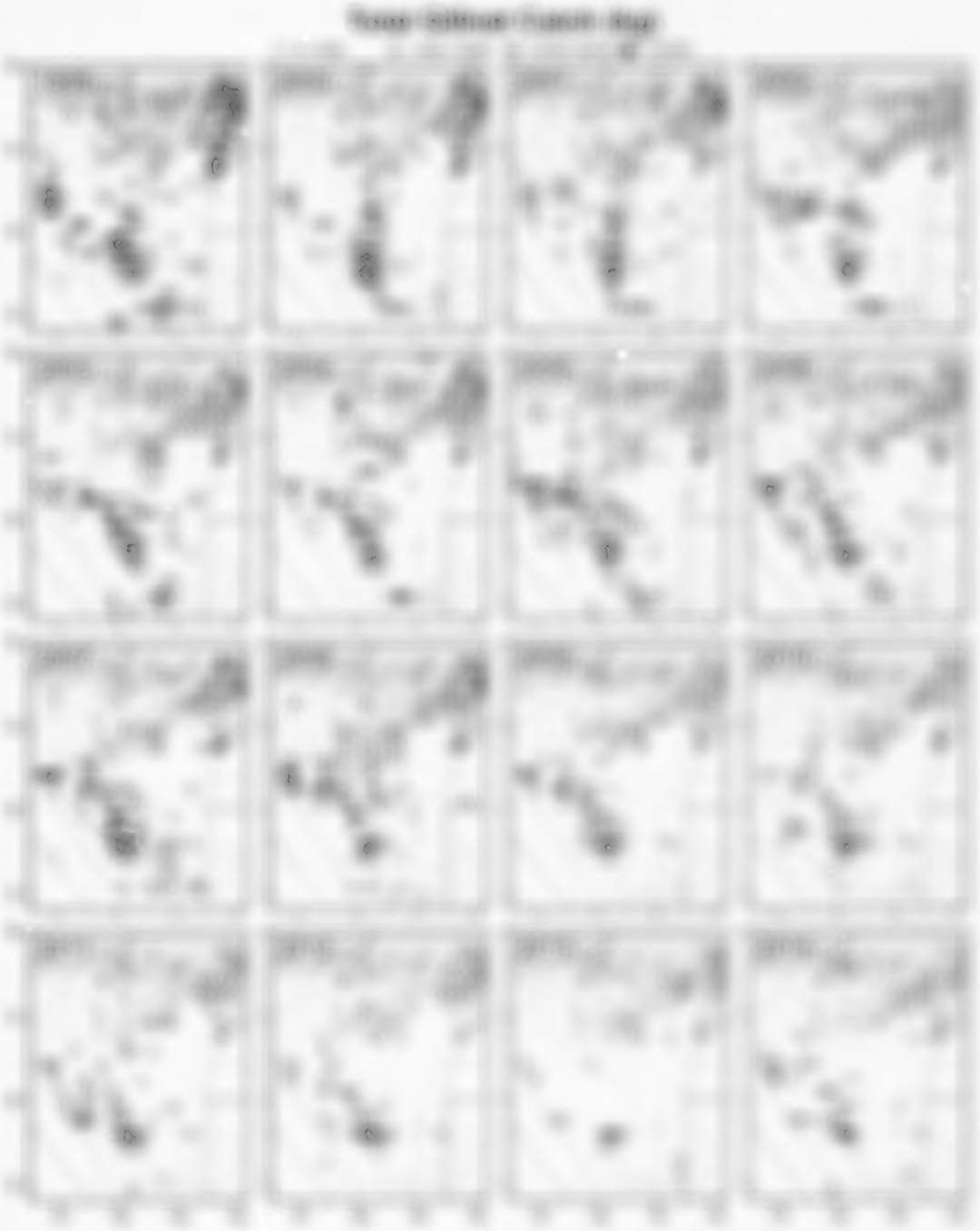


Figure 18. Global landings of Pink Cusk-Eel, *Genypterus blacodes*, and longitude as recorded in logbooks from the Chilean fishing industry, 1990-2010. Total landings are shown as black solid line and landings in New Zealand waters as dashed line.

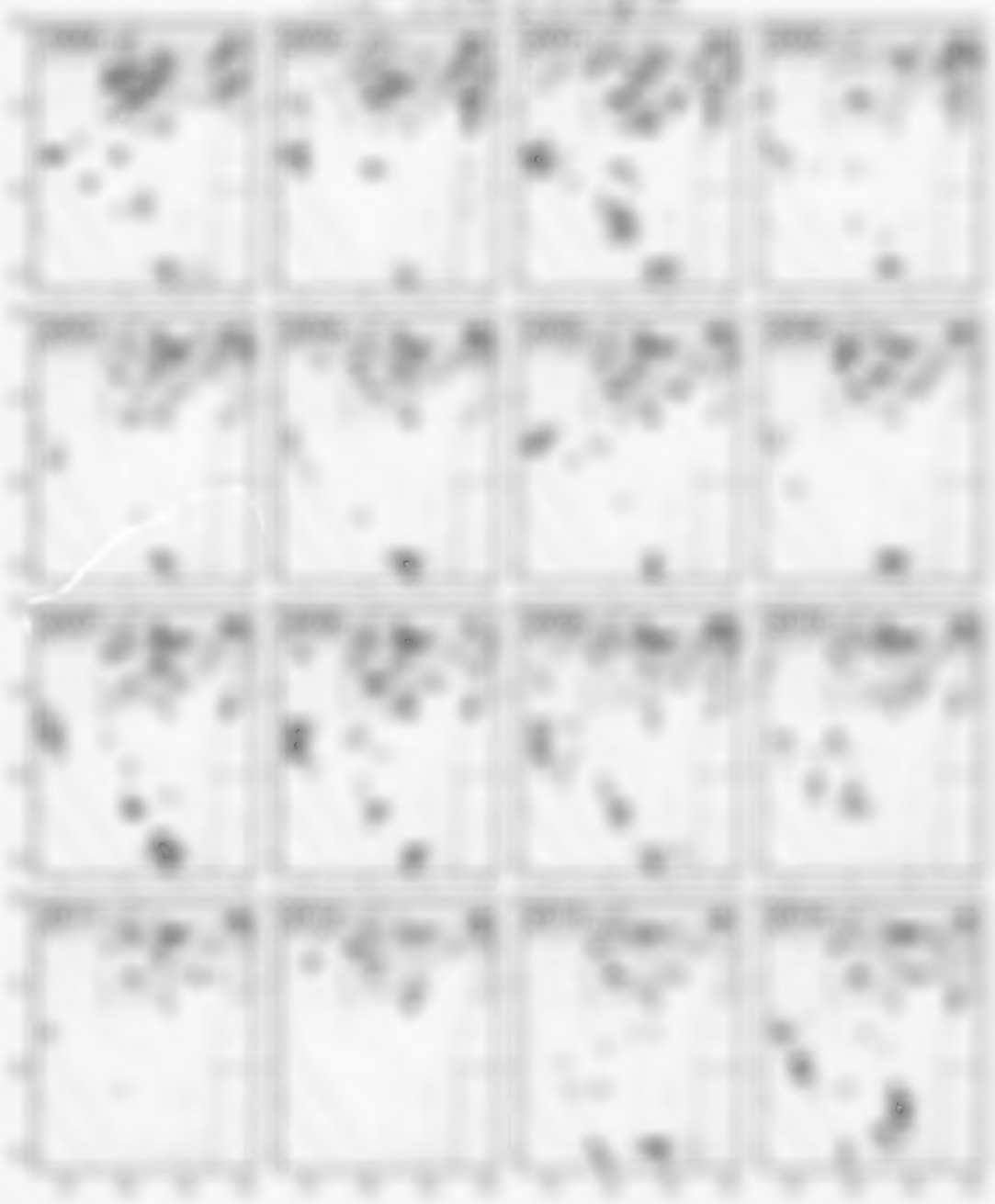


Figure 18. Longline fishing effort by year. Gray: 5-minute blocks of latitude and longitude in operation in that year. Red: 1° blocks containing 1000 or more 5-minute blocks of fishing effort. Blue: 1° blocks containing 100 to 999 5-minute blocks of fishing effort. Green: 1° blocks containing 1 to 99 5-minute blocks of fishing effort.

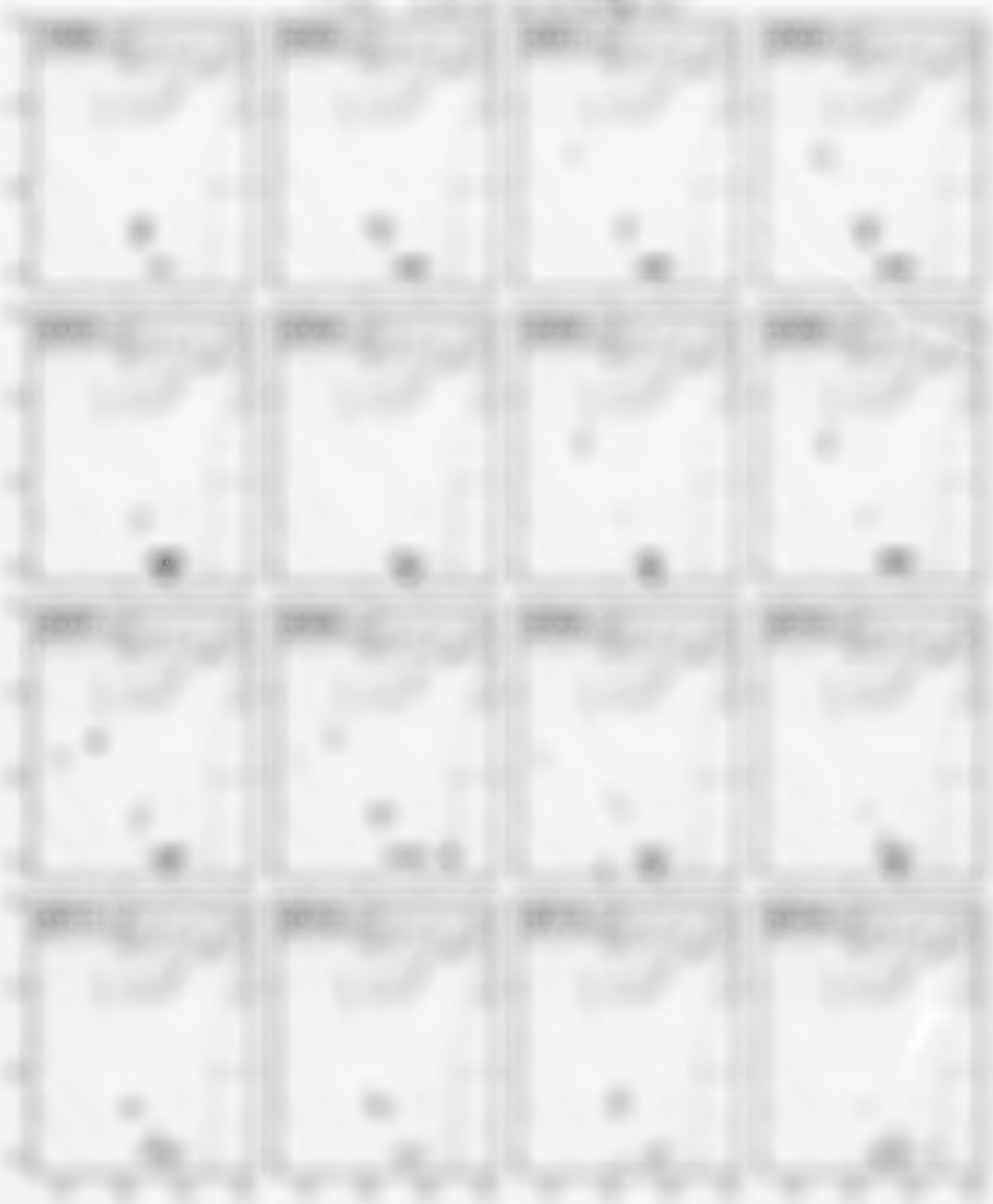


Figure 10b. Catch rates of 3Ps Cod for gillnets in 10 by 10 minute blocks of latitude and longitude as reported in logbooks from the > 19.8 fleet during 1999 to 2014. Rates are calculated as kg per net and shown as four colors corresponding to four rate categories.

Figure 10f. Catch rates of 3Ps Cod for linetrawls in 10 by 10 minute blocks of latitude and longitude as reported in logbooks from the > 35 ft. fleet during 1999 to 2014. Rates are calculated as kg per hook and shown as four colors corresponding to four rate categories.

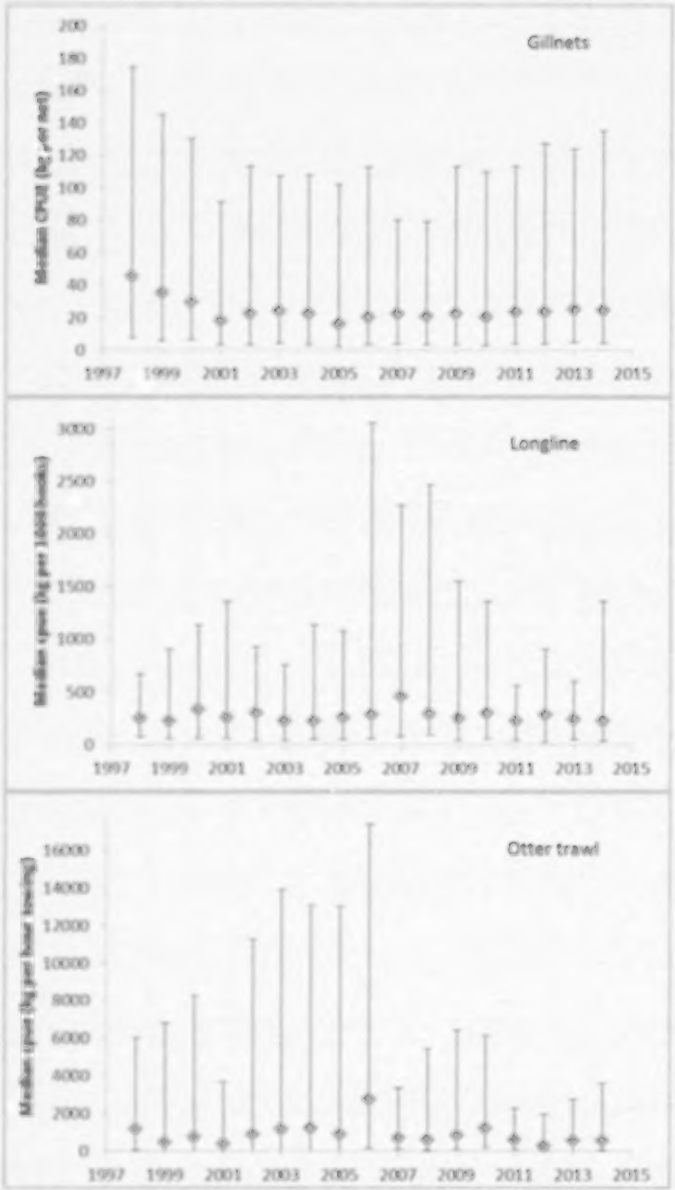
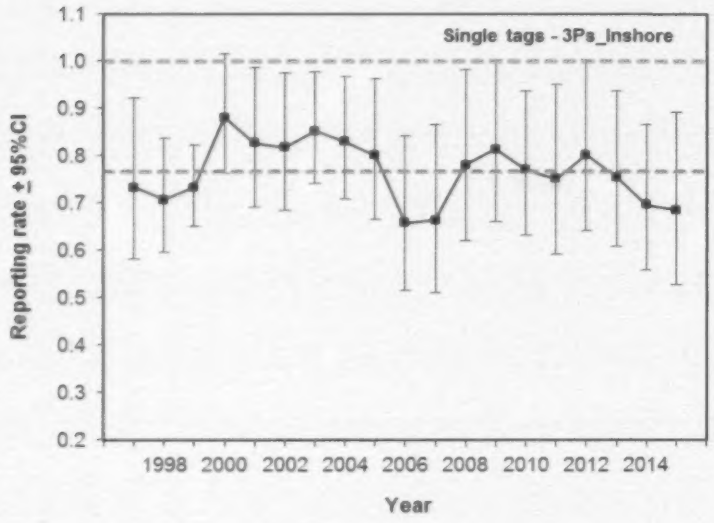


Figure 11. Median catch rates for 3Ps Cod by gillnets, linetrawls and otter trawls reported in logbooks from the > 35' fleet during 1998 to 2014. The 5th and 95th percentiles are shown.



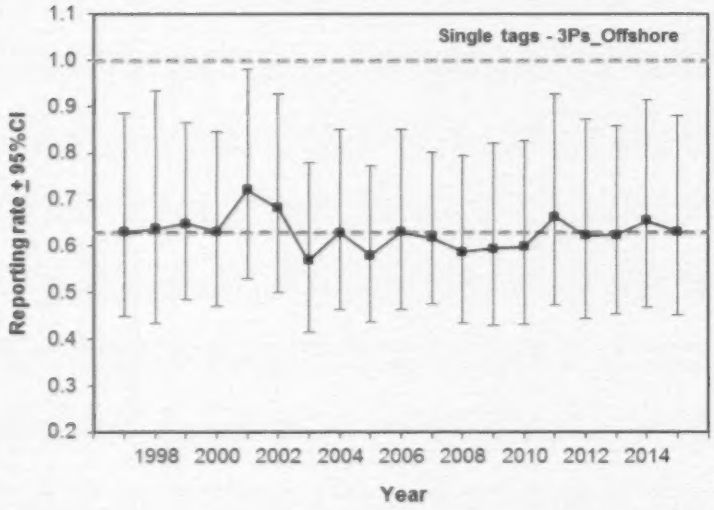


Figure 12. Trends in annual tag reporting rates (± CI's) for low reward ($10) tags based on a mixed effects logistic regression model. Horizontal dashed green line is time series average.

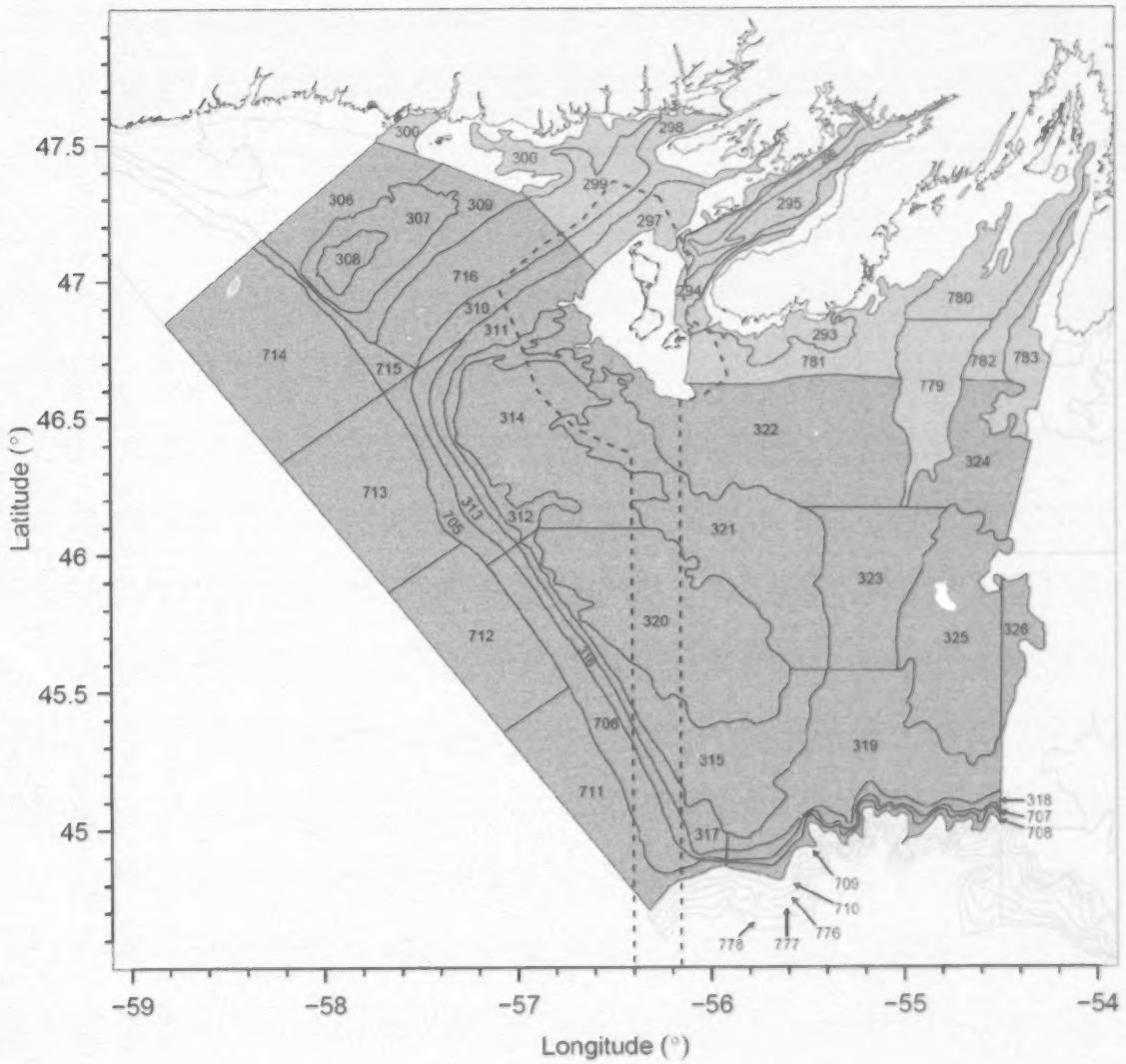


Figure 13. Stratum area boundaries and area surveyed during the DFO research vessel bottom-trawl survey of NAFO Subdiv. 3Ps. Offshore strata are shaded blue. Inshore strata were added in 1994 (strata 779-783) and 1997 (strata 293-300) and are shaded green. The dashed line represents the boundary of the French economic zone.

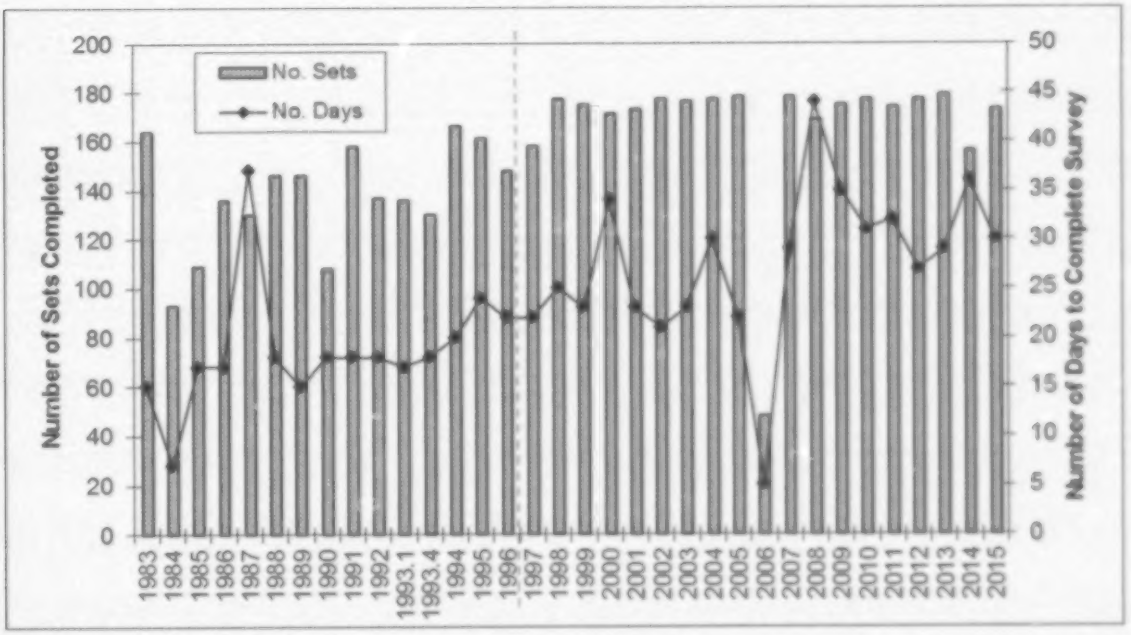


Figure 14. Number of research vessel survey sets completed during surveys of NAFO Subdiv. 3Ps, and the number of days required to complete these sets over 1983-2015. Survey coverage was expanded to present levels (i.e. covering all inshore and offshore index strata) in 1997 (dashed vertical line).

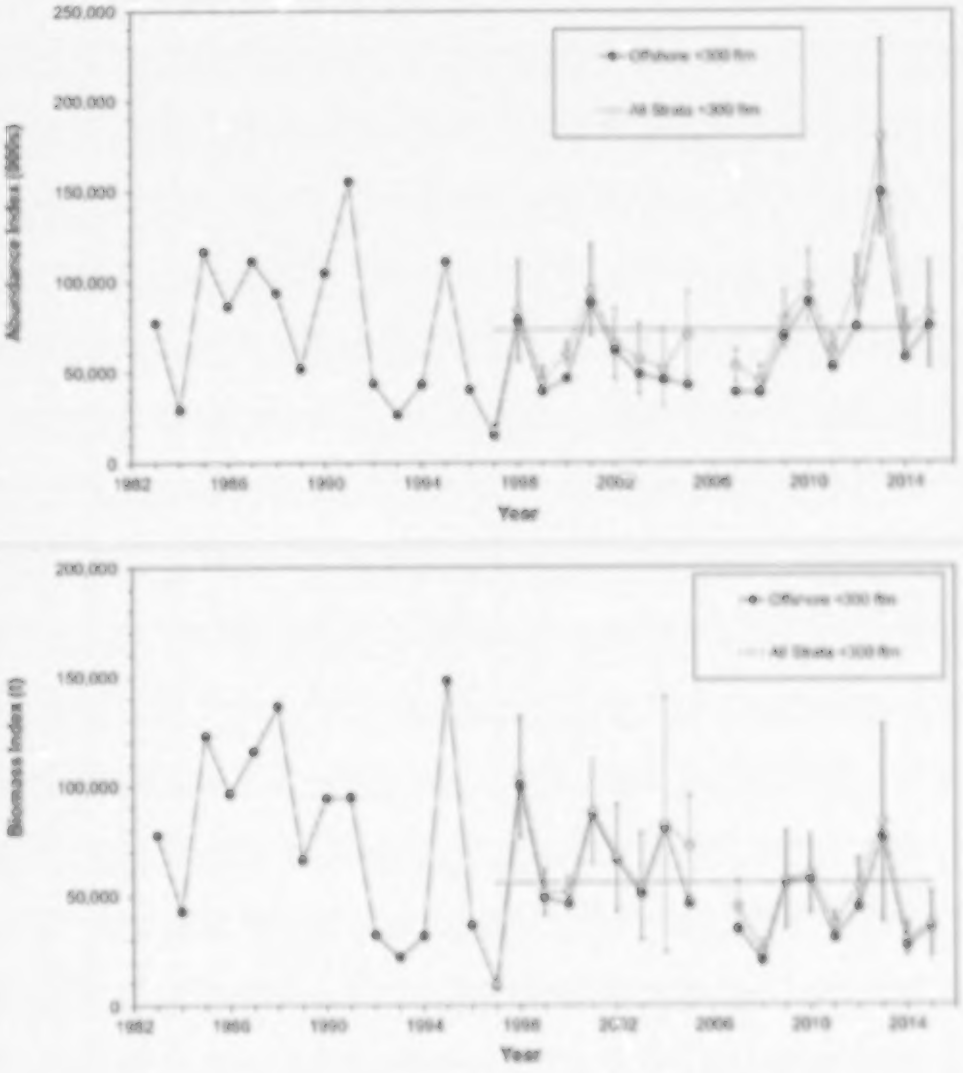


Figure 15. Abundance (upper panel) and biomass (lower panel) indices for cod in NAFO Subdiv. 3Ps from DFO research vessel bottom trawl surveys of index strata during winter/spring from 1983 to 2014. Error bars show plus/minus one standard deviation. Open symbols show values for the augmented survey area that includes additional inshore strata added to the survey in 1997. Dashed horizontal lines are means of the time-series for all index strata.

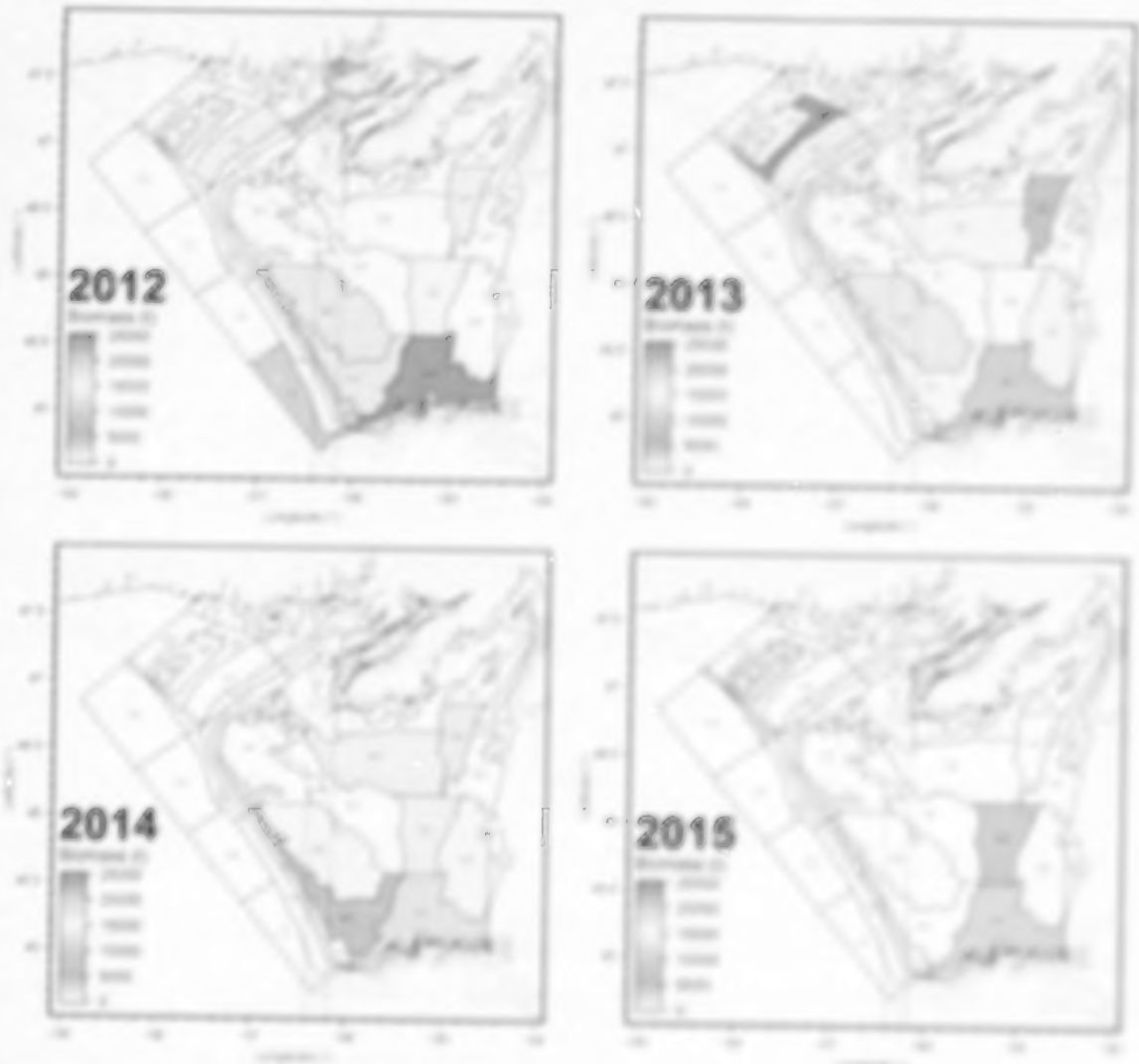


Figure 16. Stratum-specific biomass estimates of cod in Subdiv. 3Ps based on the DFO 4Vn survey.

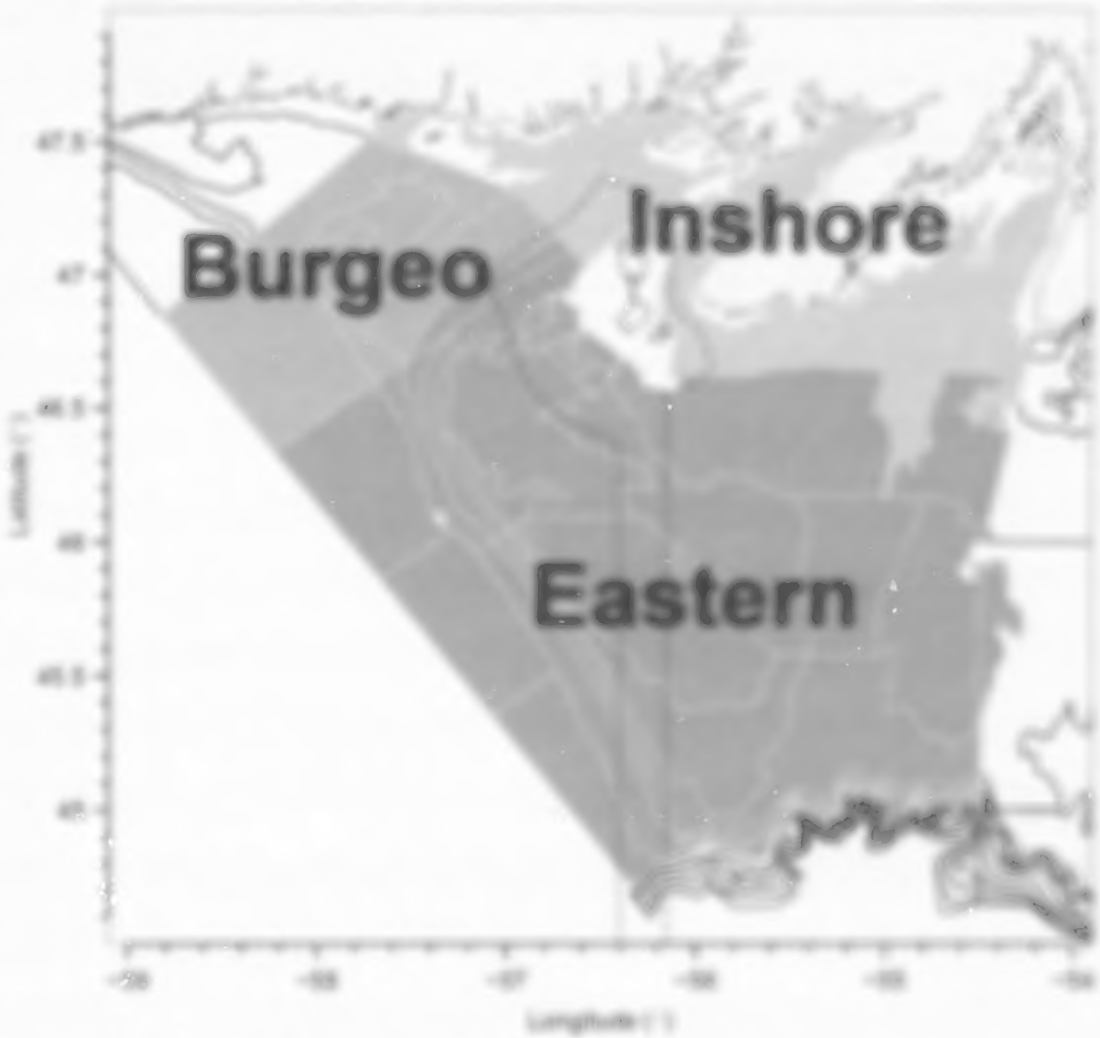


Figure 17. NAFO Subdiv. 3Ps management zone illustrating the allocation of survey strata into 'Inshore', 'Burgeo', and 'Eastern' regions. Survey trends for the three regions are depicted in Fig. 17.

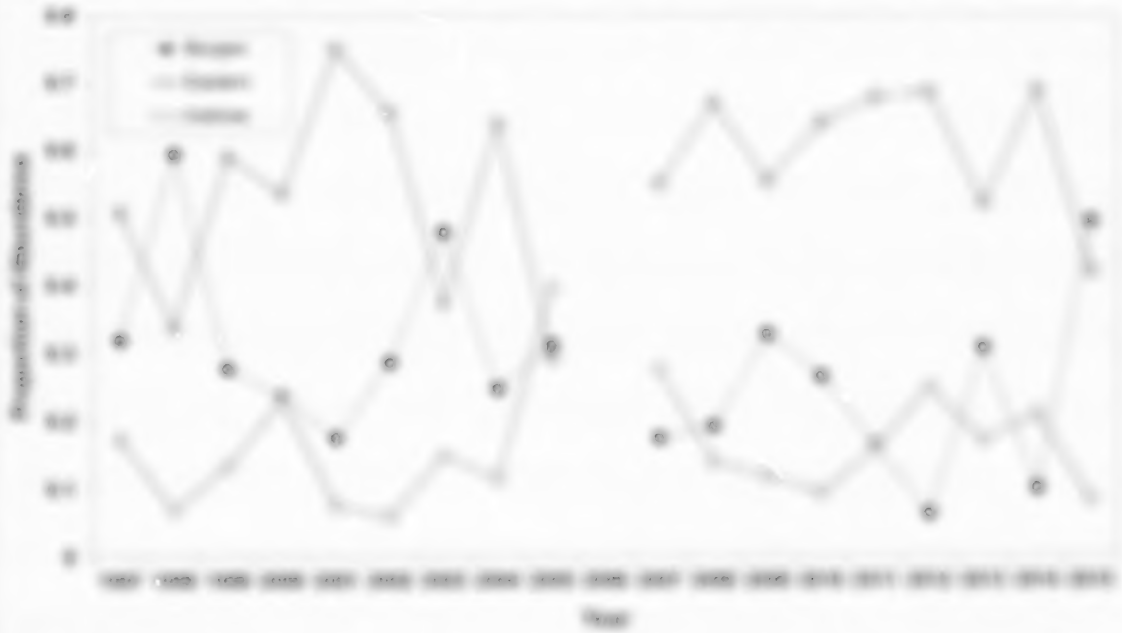


Figure 18. Trawl abundance index for cod in various regions of NAFO Subdiv. 3Ps from DFO research vessel bottom trawl surveys during winter/spring from 1987 to 2015. The 1996 survey was not completed. The Campelen trawl was used in all surveys.

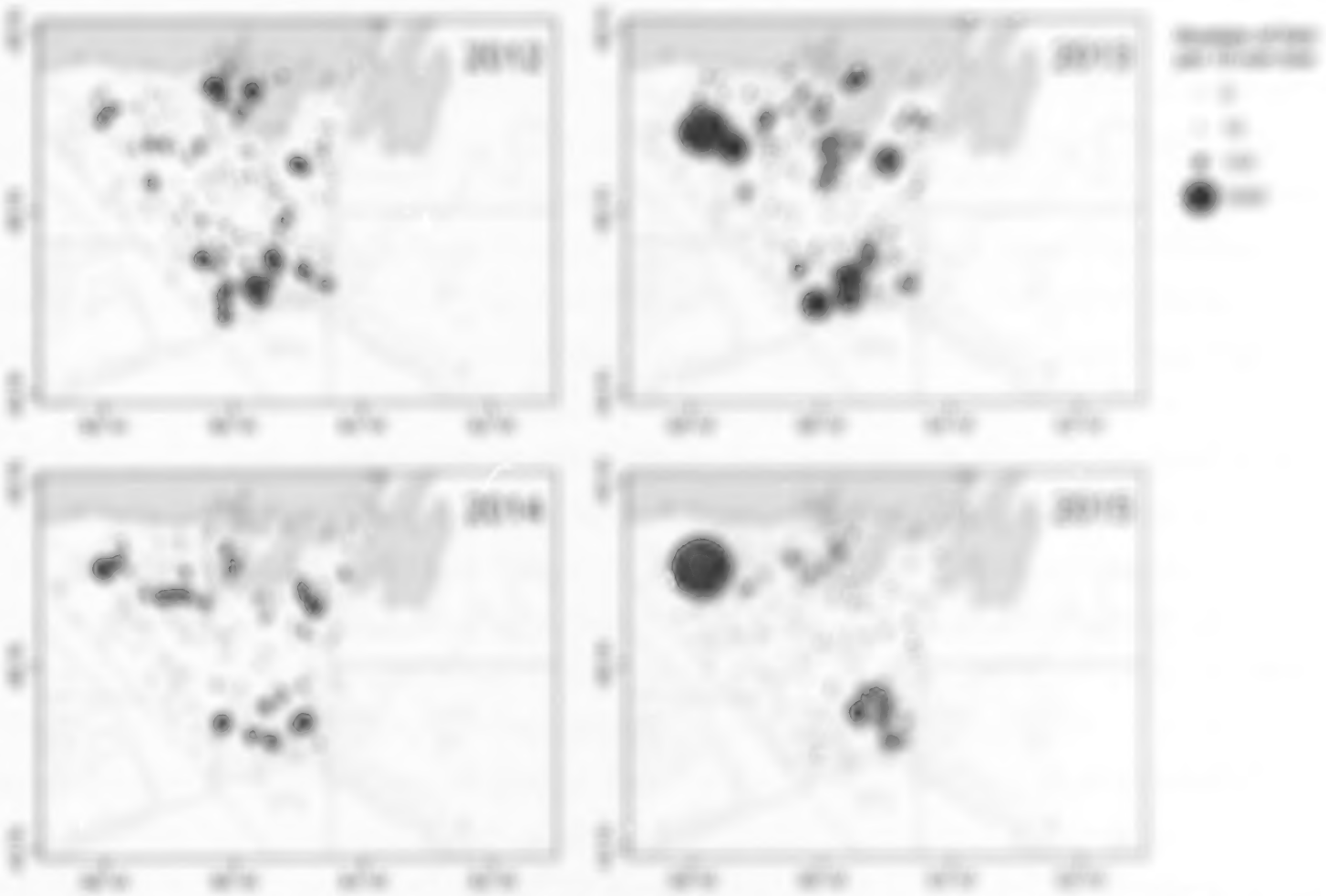


Figure 10a. Age aggregation distribution of cod catches (ind. per tow) from the April ERS research vessel surveys (1996-2015 (2) Bubble size is proportional to numbers caught.

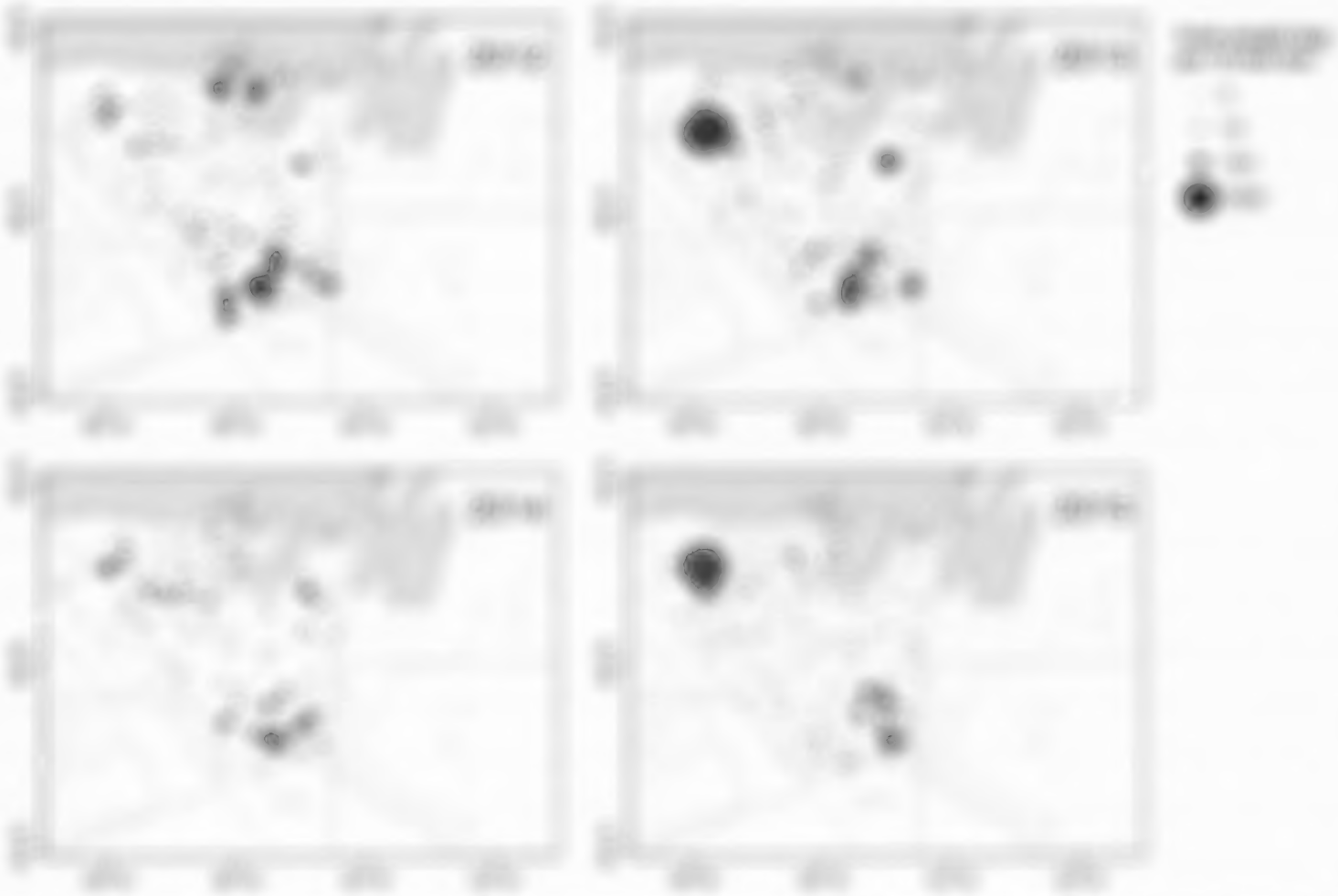


Figure 7. The aggregation mechanism of iron species revealed via two-time-step operando XAS measurements carried out during a CO$_2$RR cycle. (**A**) and (**B**) Fe K-edge XANES and corresponding Fe wavelet transform (WT) contour plots recorded at the first time step (**A**) and the second time step (**B**). (**C**) Fe K-edge XANES and corresponding Fe WT contour plots recorded at the second time step (**C**) of the CO$_2$RR cycle. (**D**) Fe K-edge XANES and corresponding Fe WT contour plots recorded at the second time step (**D**) of the CO$_2$RR cycle. (**E**) Comparison of the Fe K-edge XANES spectra recorded at the first time step (**A**) and the second time step (**B**). (**F**) Comparison of the Fe K-edge XANES spectra recorded at the second time step (**C**) and the second time step (**D**). (**G**) Comparison of the Fe K-edge XANES spectra recorded at the second time step (**B**) and the second time step (**D**). (**H**) Comparison of the Fe K-edge XANES spectra recorded at the second time step (**C**) and the second time step (**D**).

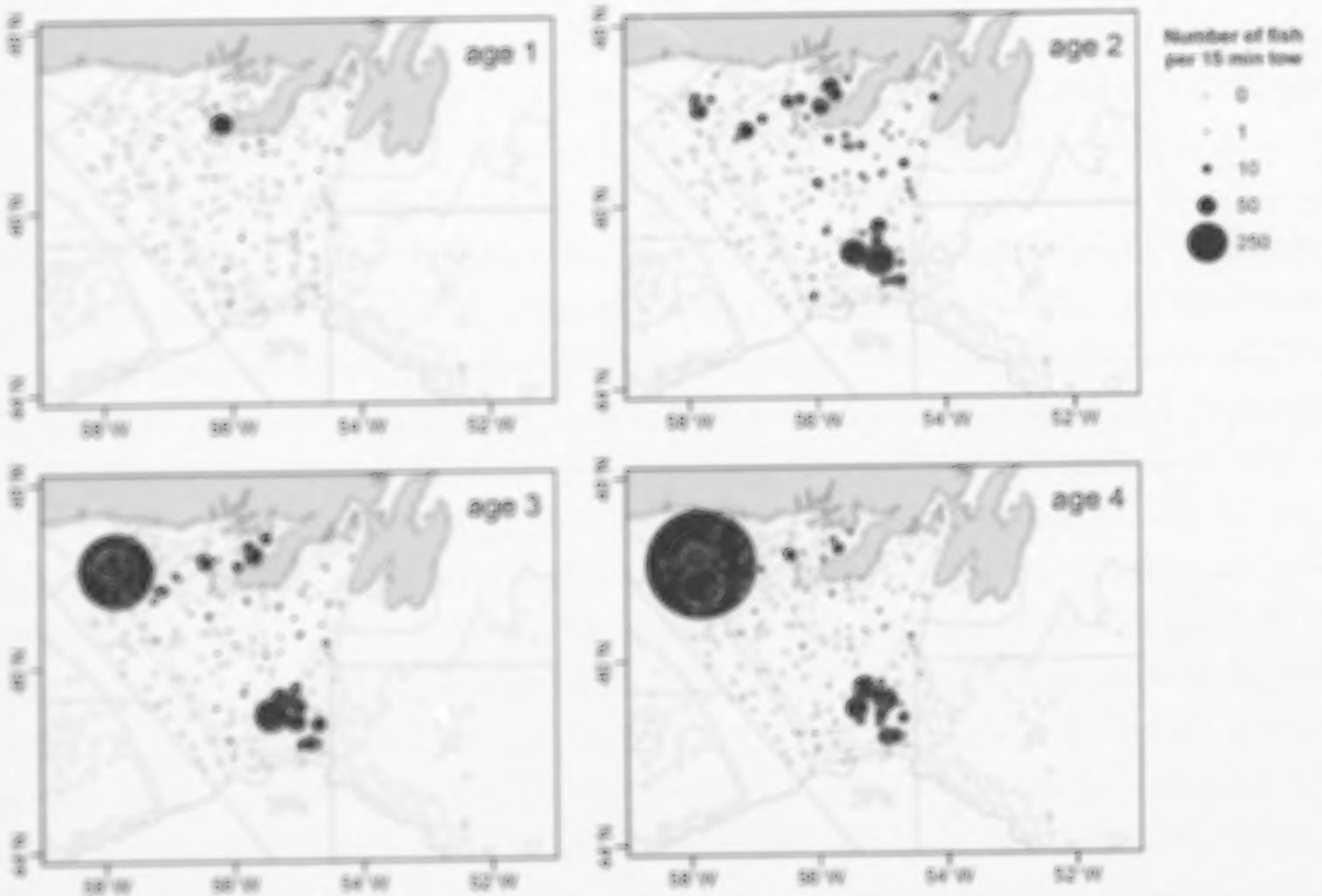


Figure 18c. Age dis-aggregated distribution of cod catches (nos. per tow, ages 1-4) from the April 2015 DFO research vessel survey of NAFO Subdiv. 3Ps. Bubble size is proportional to numbers caught.

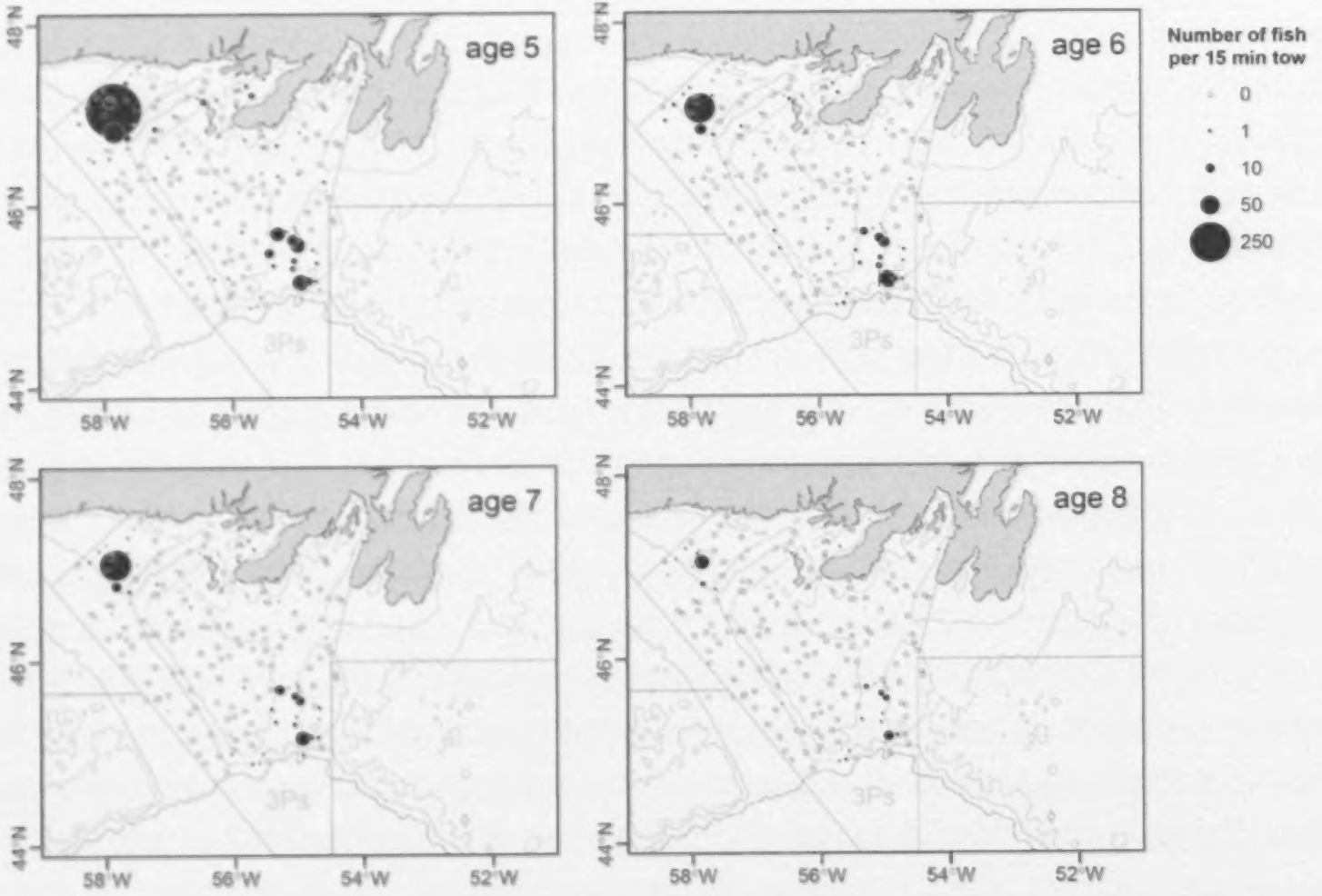


Figure 19c. Continued.

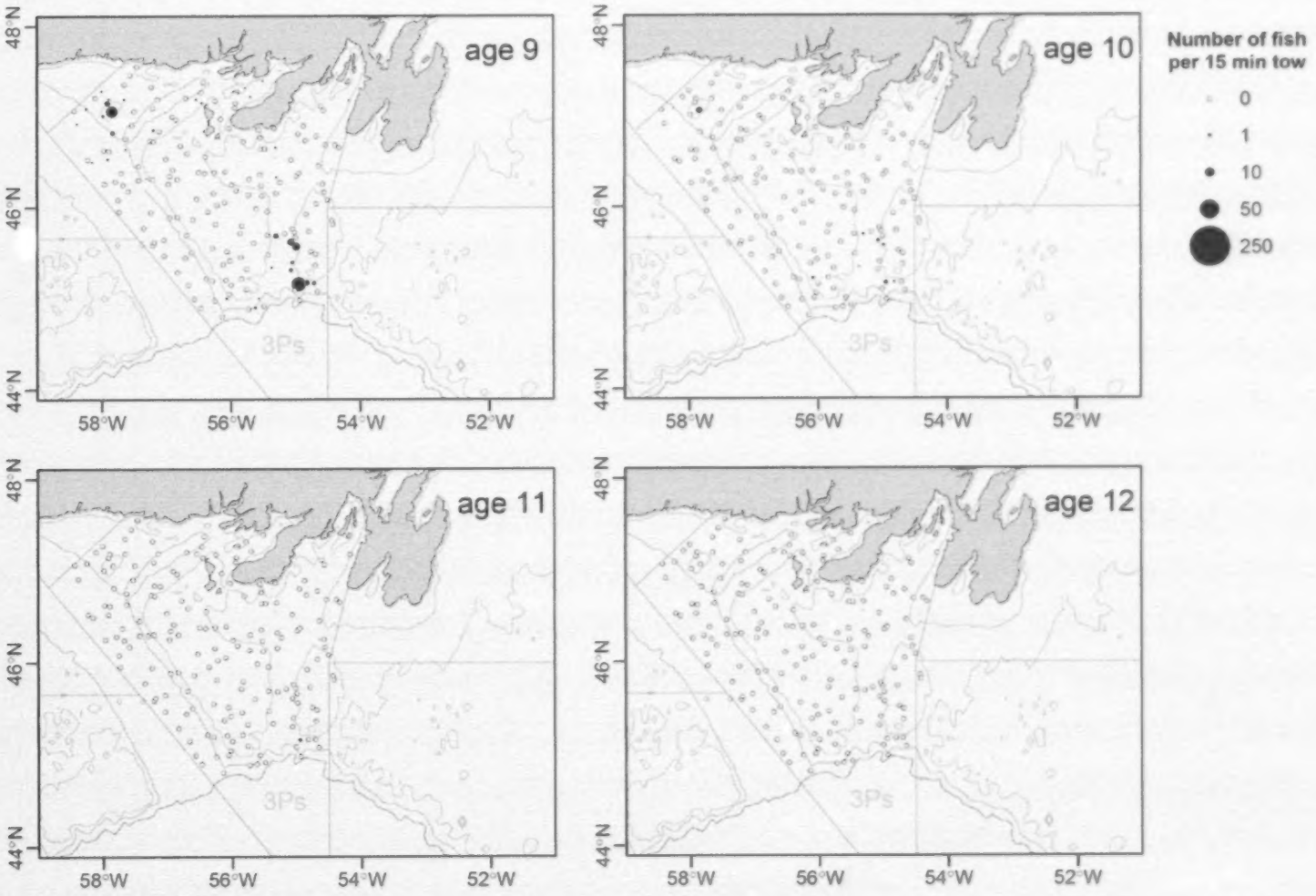


Figure 19c. Continued.

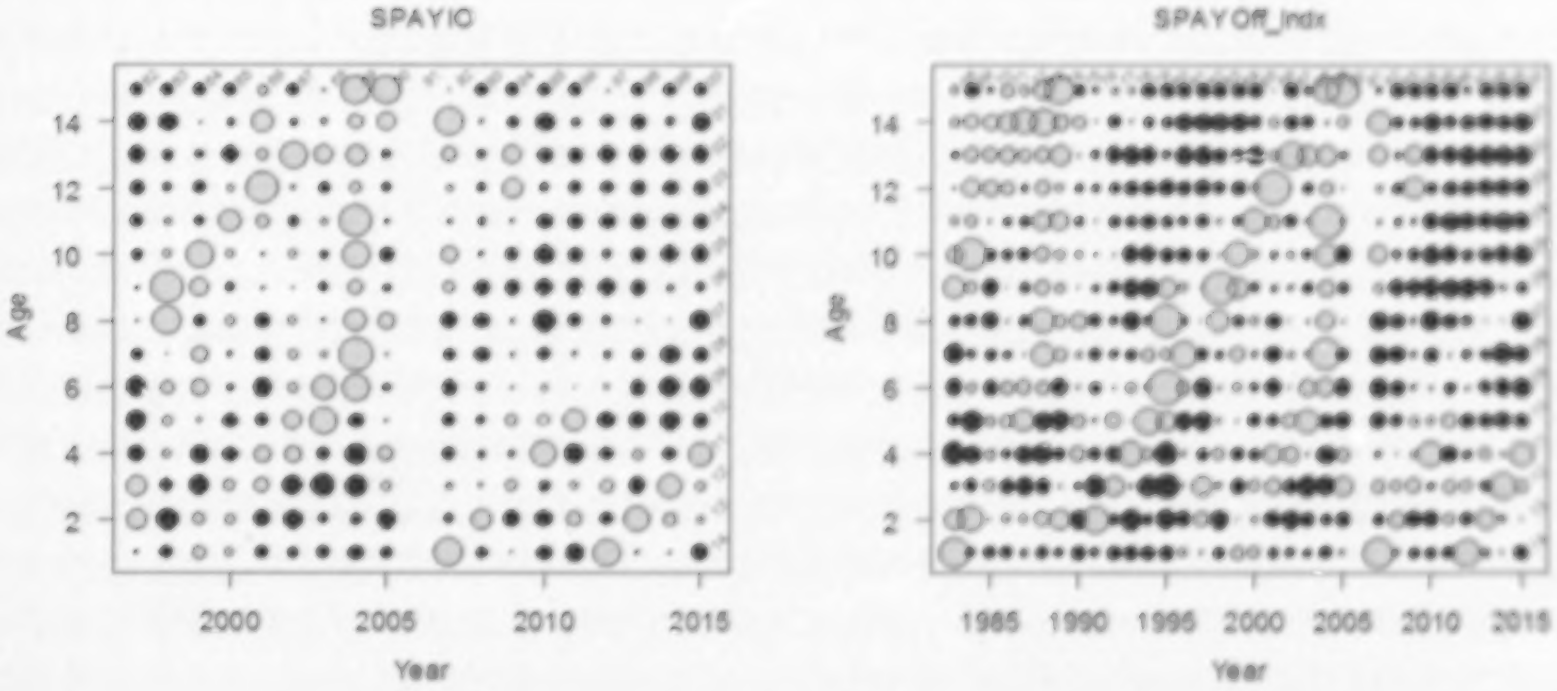


Figure 20. Standardized age-disaggregated catch rates from the spring bottom trawl survey of Subdiv. 3Ps. Catch rates (mean nos per tow) were converted to proportions within each year. Values were standardized by subtracting the mean proportion and dividing by the standard deviation of the proportions computed across years. Symbol sizes are scaled and values greater than average are shown as grey circles, average values are shown as small dots, and less than average values are shown as black circles. Labels in the upper and right margins identify cohorts. Left panel includes the 1997-2015 "All Strata < 300 fm" data, and panel at right includes data which comprise the "Offshore" index (1983-2015).

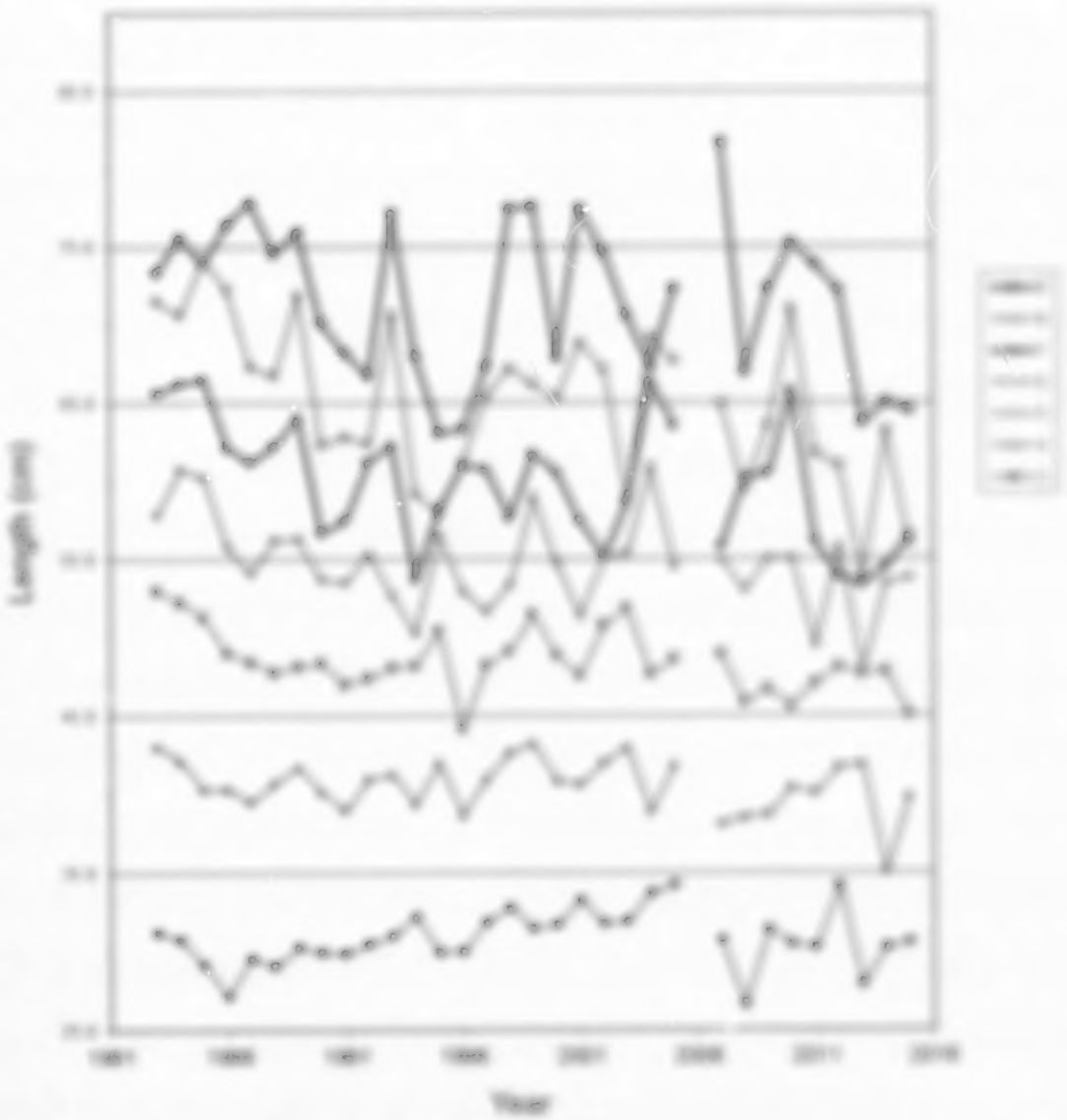


Figure 21a. Mean length at ages 3-6 of cod in Subdiv. 3Pn during 1965-2015 from sampling during DFO bottom-trawl surveys in winter-spring.

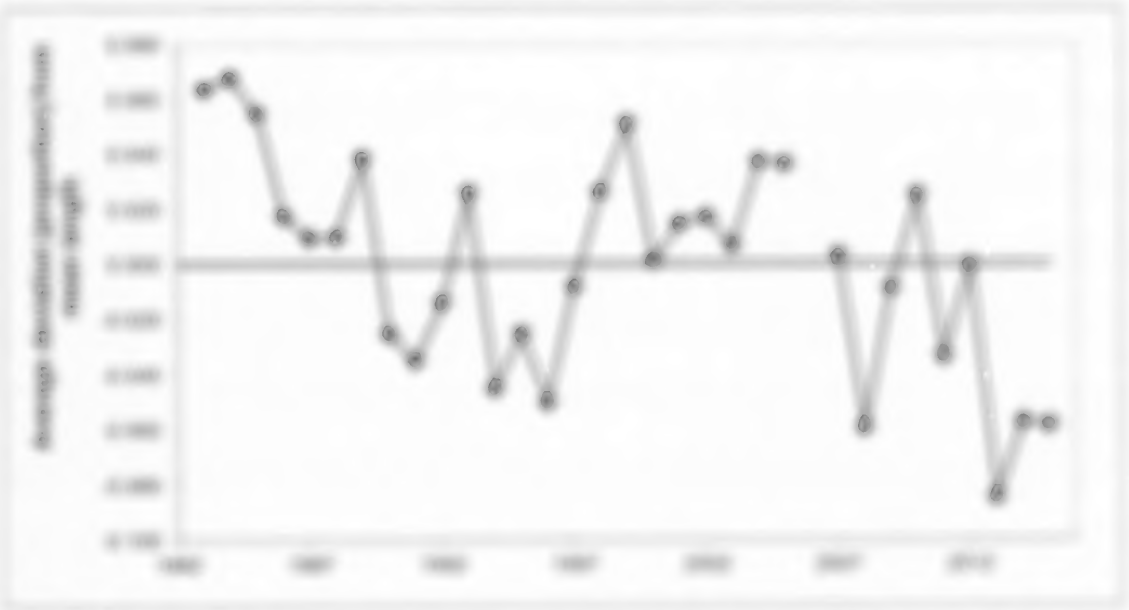


Figure 216. Average proportion deviation from mean length at age for ages 3-8 Cook Q4Q3 bottom trawl surveys from 1983-2015.

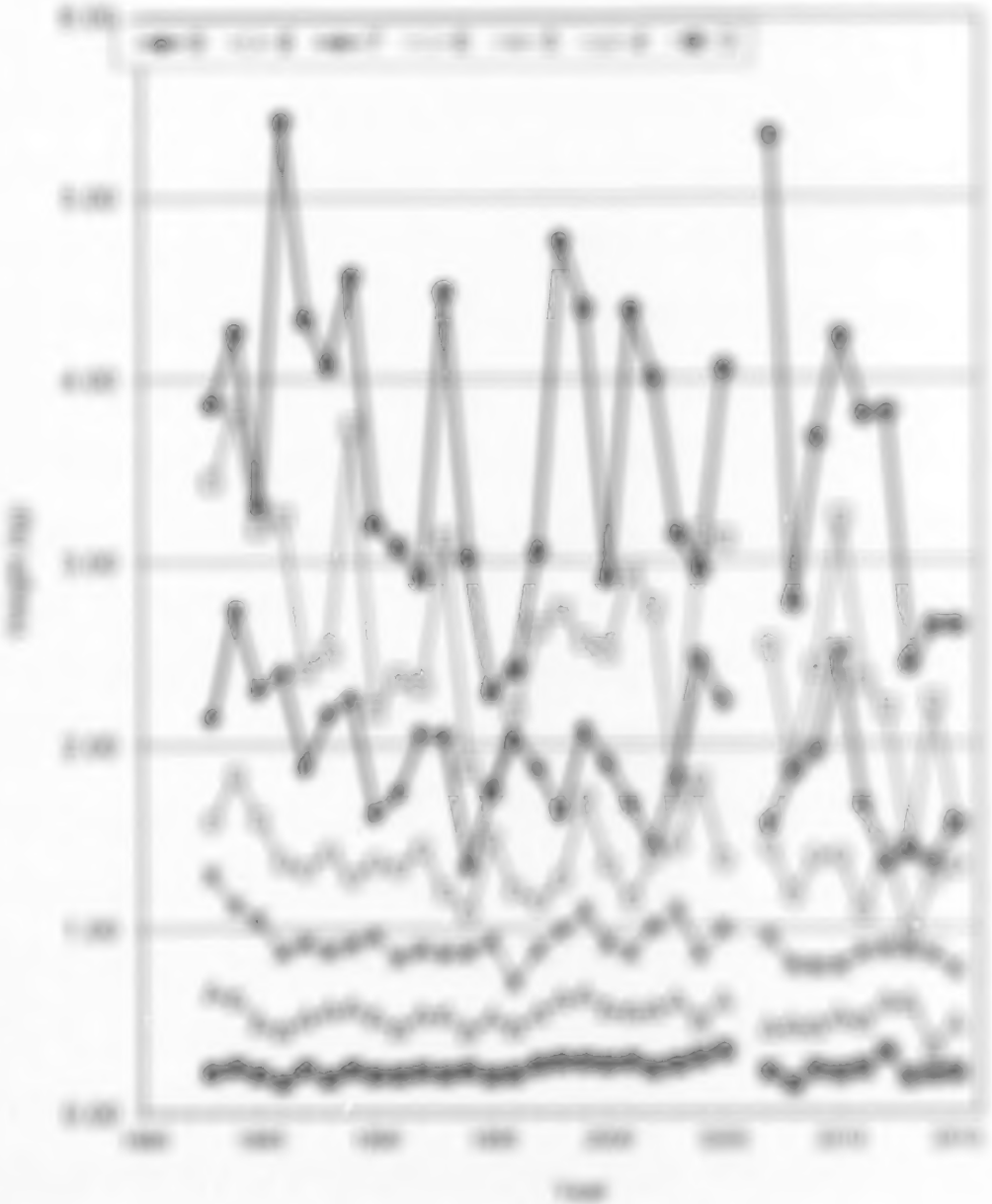
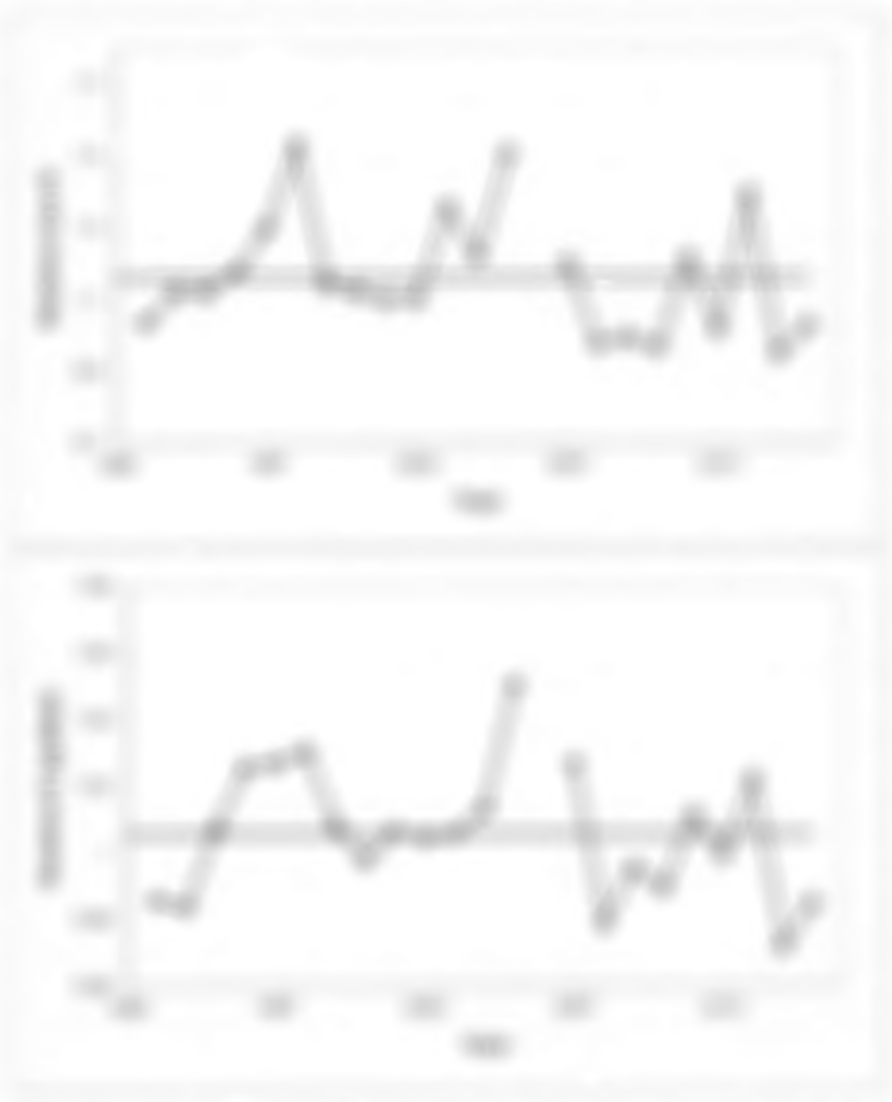


Figure 22a. Mean round weight at age (kg) of cod sampled during GFS bottom trawl surveys in NAFO Subdiv. 3Pn in winter-spring, 1983–2015.

Year



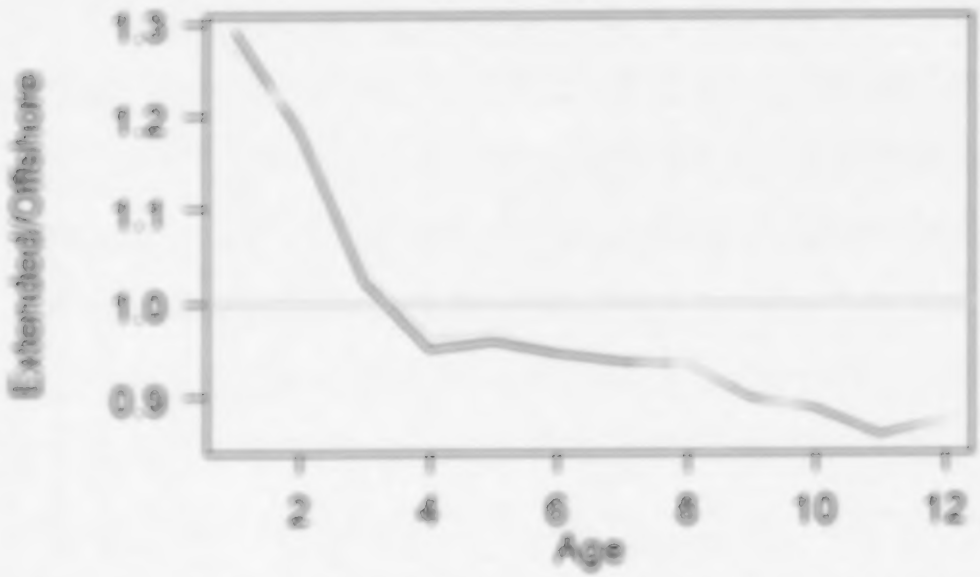


Figure 29. Age-specific ratio of the extended survey edition to the offshore survey edition (each index averaged over 1997-2010). Grey line indicates ratios from previous assessment, where averages were computed over 1997-2010.

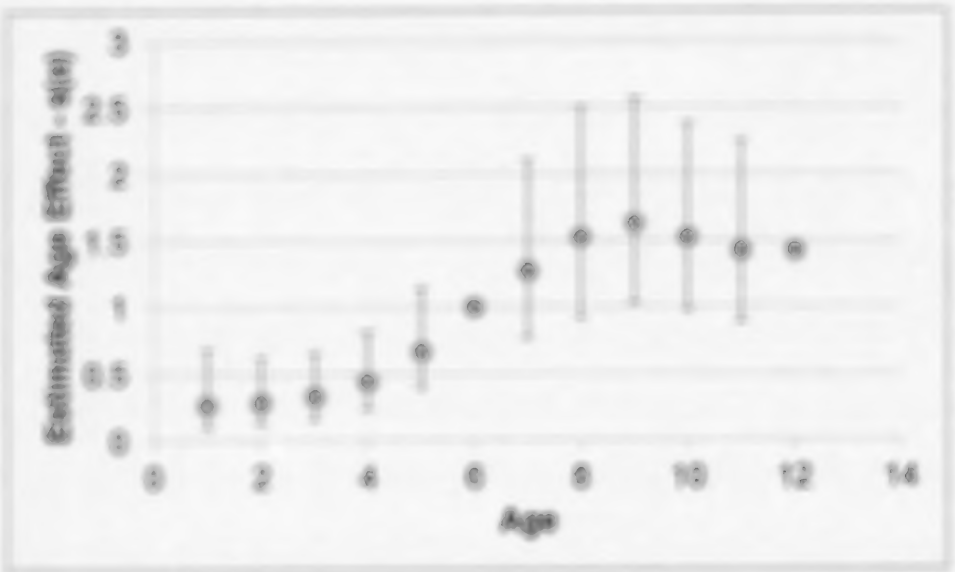


Figure 30. Estimated age-effects from SURBA retrospective analysis, with 95% confidence interval. Age 6 is arbitrarily chosen as a reference age (and set to a value of 1), and the effect at age 12 is fixed at the level estimated for age 11.

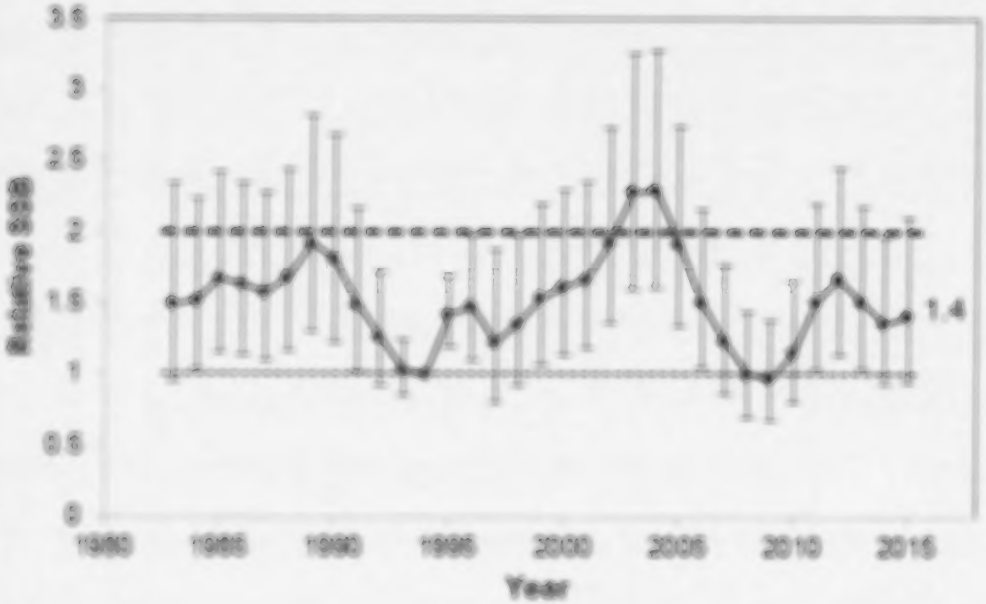


Figure 27a. Estimates of spawning stock biomass (SSB) relative to B_{1994} from SURBA cohort analysis model (i.e., estimates are divided by 1994 SSB), with 95% confidence interval.

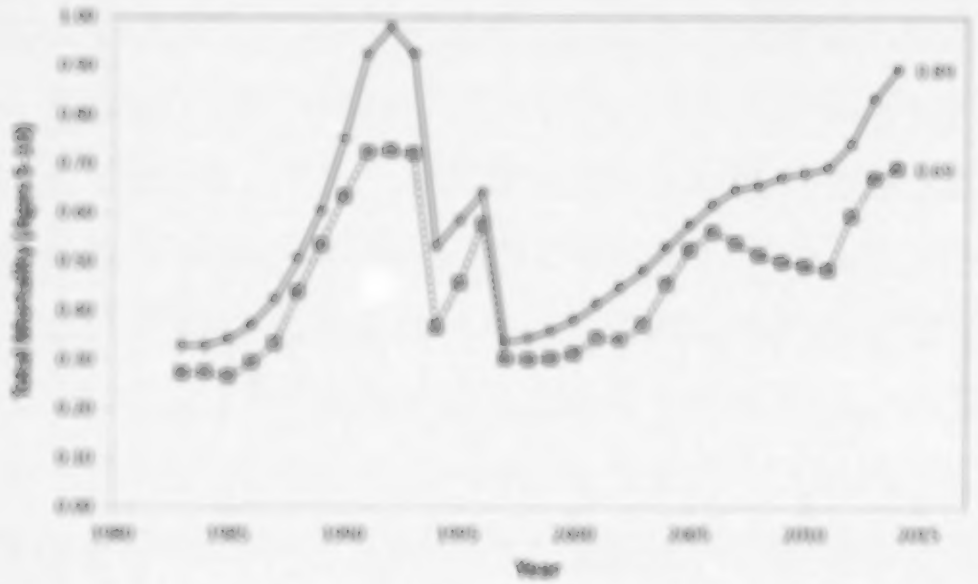


Figure 27b. Estimates of total mortality (Z) from a SURBA cohort analysis model, averaged over ages 5-10. Solid line: average annual mortality; dashed line: average annual mortality weighted by population size at ages 5-10. Text label indicates the estimated total mortality for 2014.

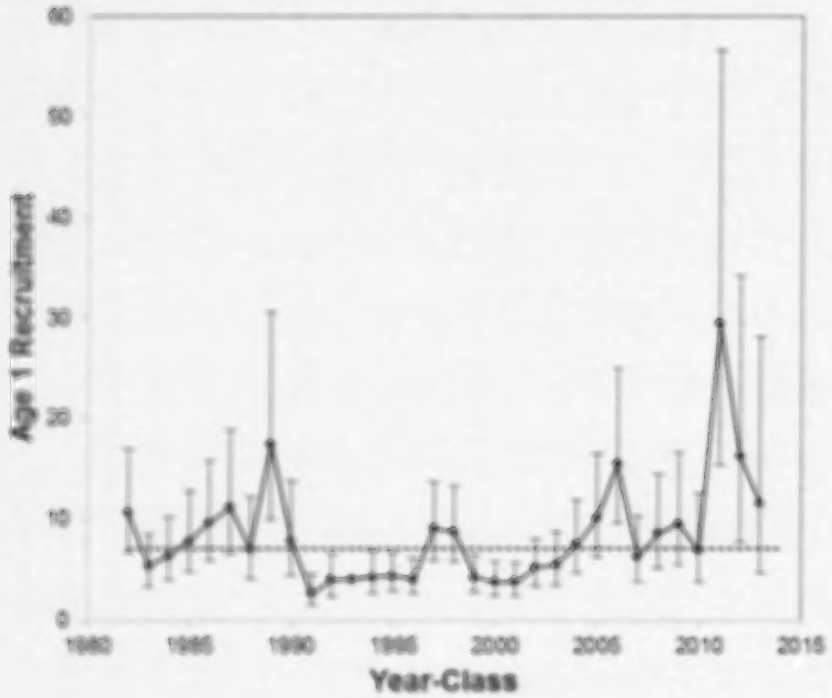


Figure 27c. Estimates of age 1 recruitment from SURBA cohort analysis model.

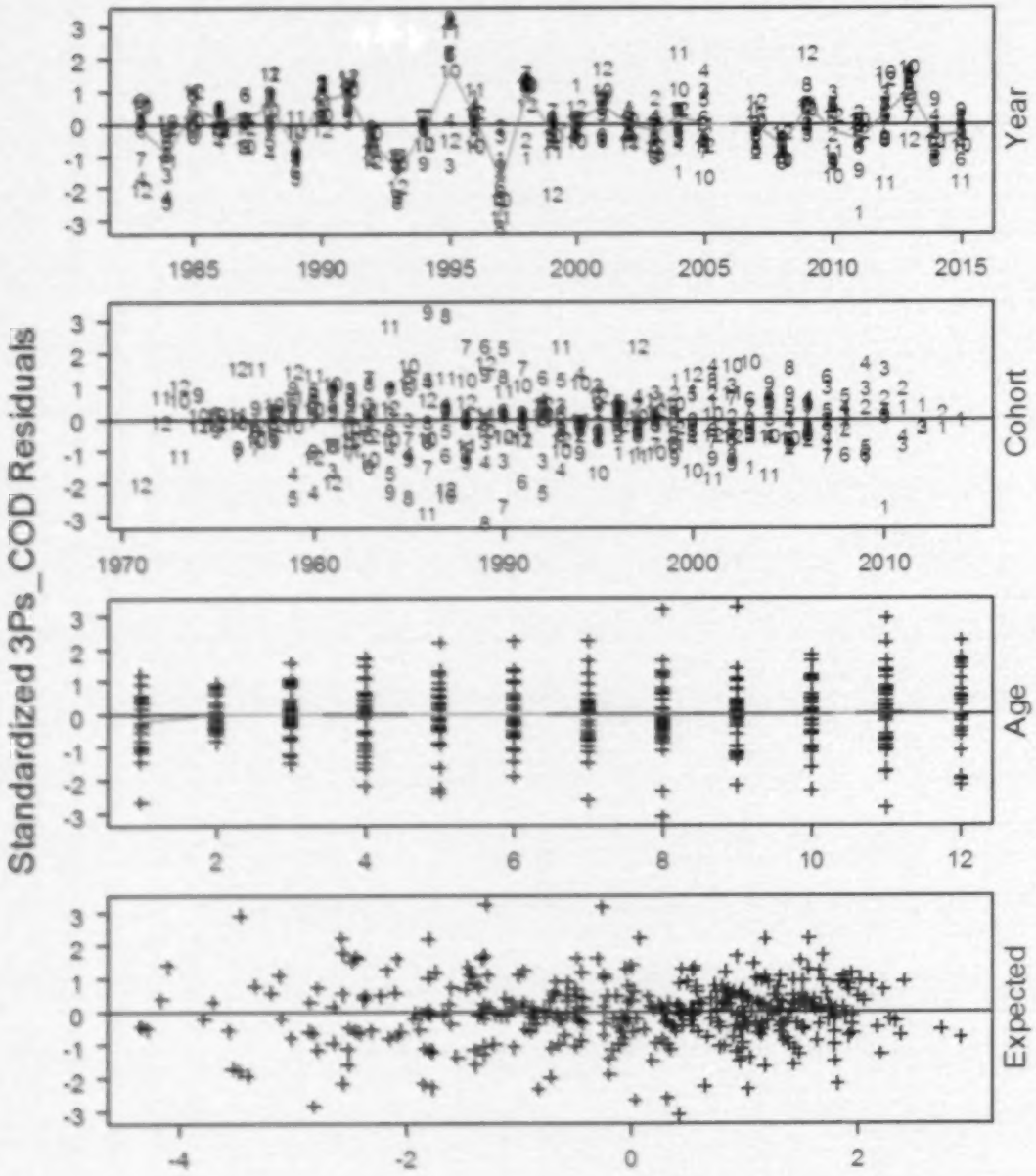


Figure 28. Standardized residuals from SURBA cohort analysis. Panels show residuals plotted year, cohort, age, and expected value, respectively.

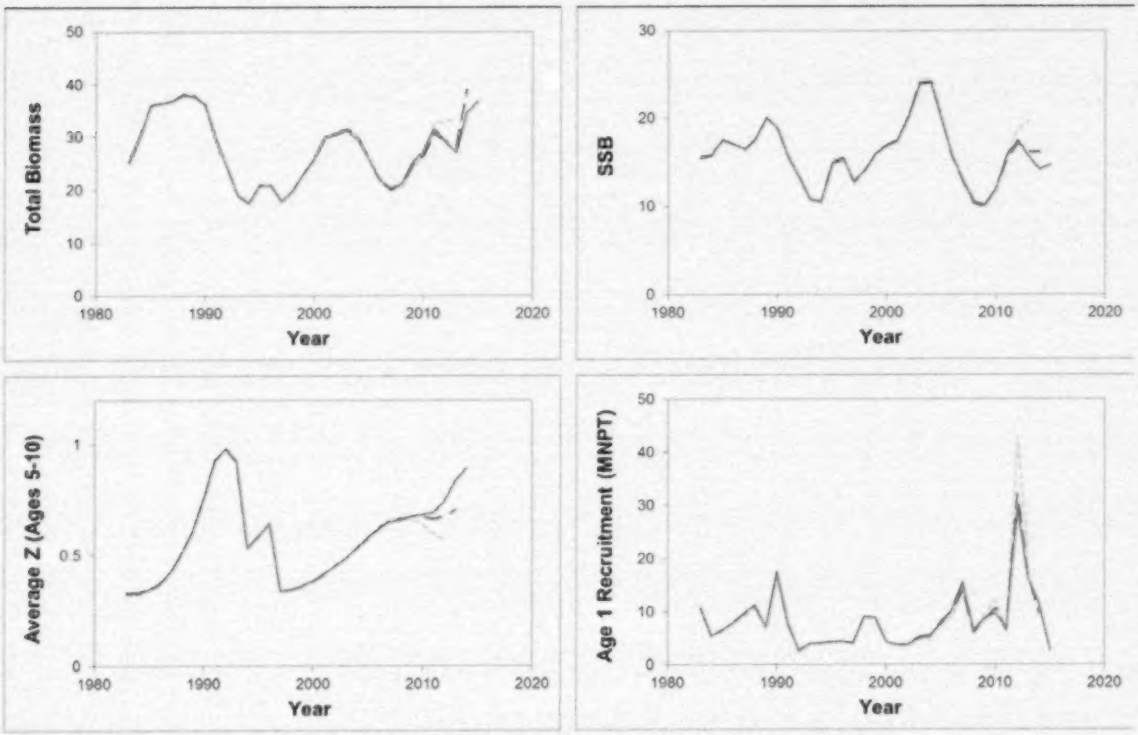


Figure 29. Retrospective patterns comparing the three most recent assessments for 3Ps cod based on a SURBA cohort analysis model.

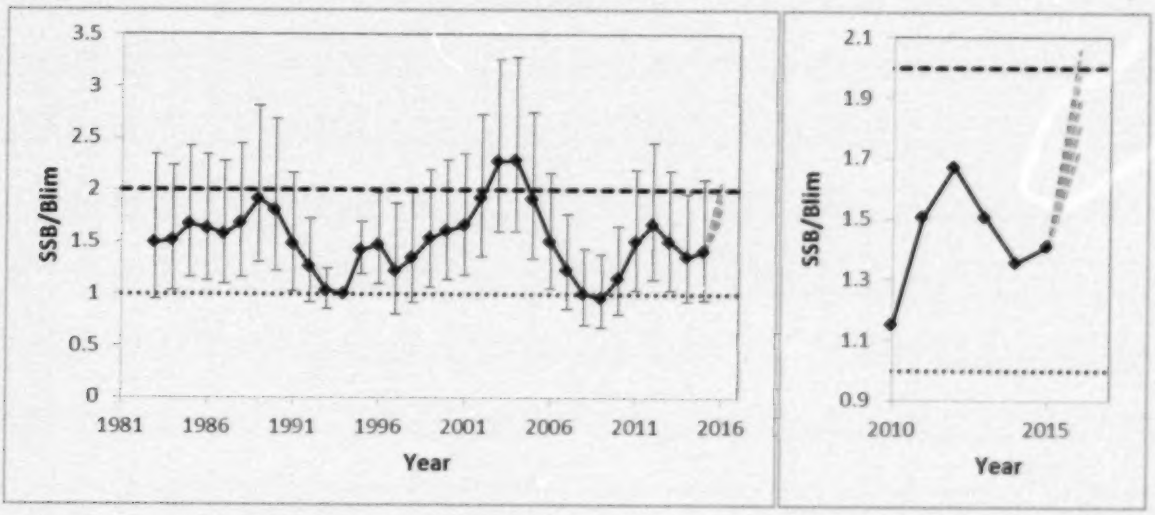


Figure 30. Projections of spawning stock biomass from SURBA cohort analysis (refer to text for details). The panel on the right provides a higher magnification look at the last five years of SSB and the projections.

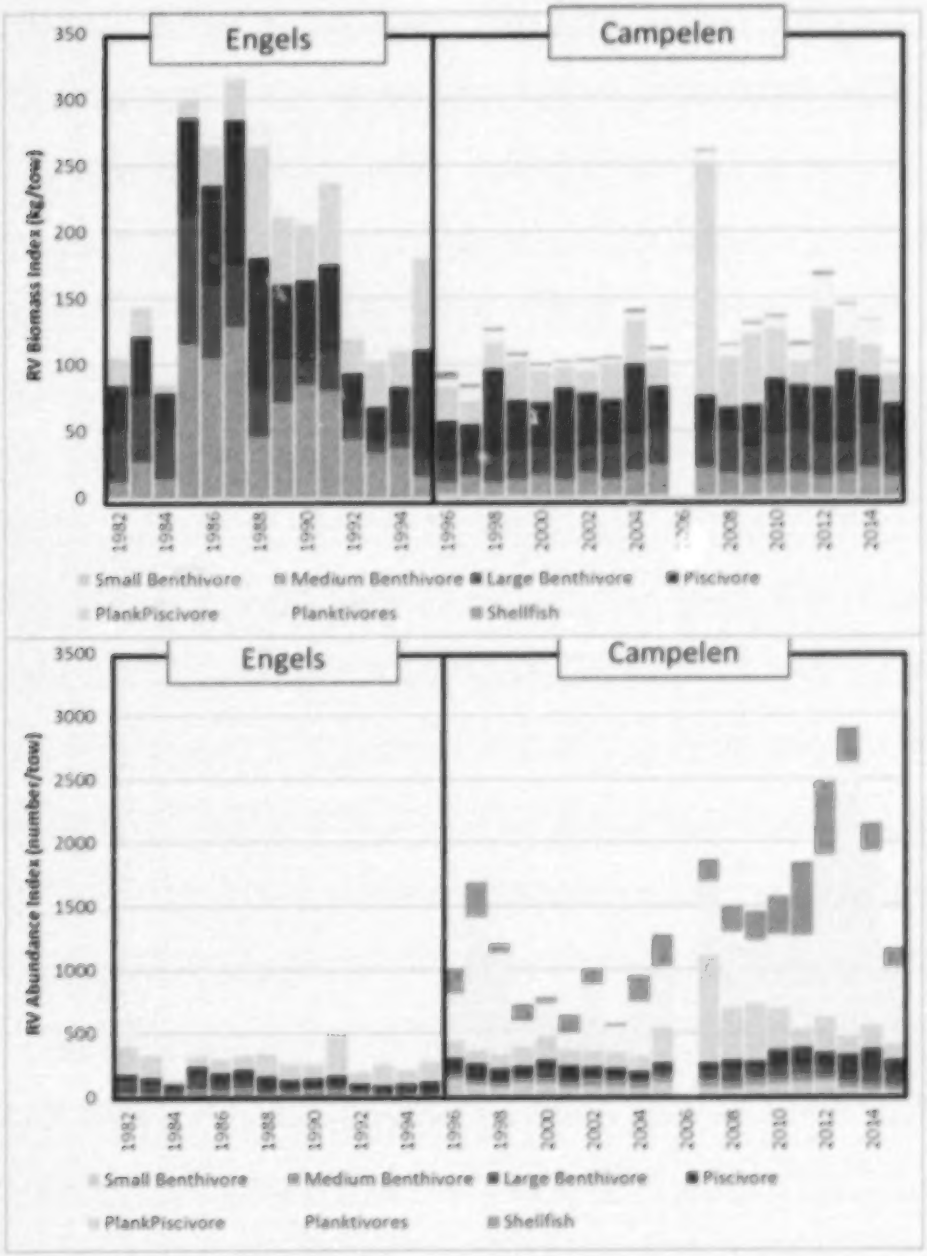


Figure 31. RV biomass (top) and abundance (bottom) from DFO 3Ps Spring survey by fish functional groups, with indication of the gear used in the survey (Campelen and Engels). Index values are not directly comparable between gears; the Campelen series also includes the Shellfish functional group.

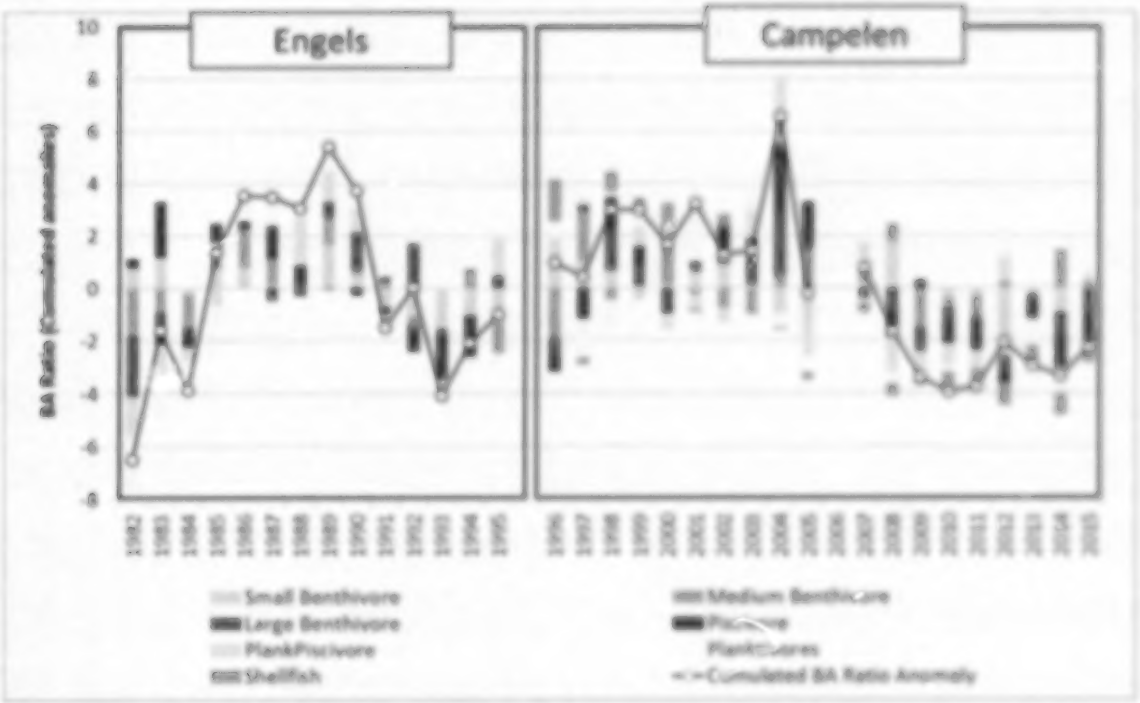


Figure 32. RV biomass/abundance ratio (BA ratio) normalized anomalies from DFO 3Ps Spring survey by fish functional groups, with indication of the gear used in the survey (Campelen and Engels). The colored bars indicate the anomalies for each functional group, while the line indicates the cumulated anomaly. BA ratio values are not directly comparable between gears.

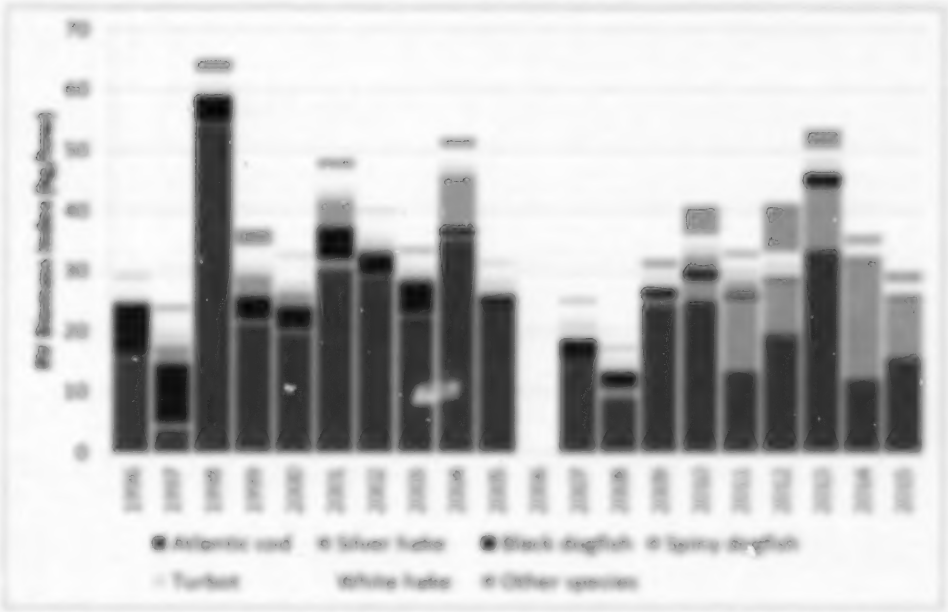


Figure 33. RV biomass from DFO 3Ps Spring survey for Piscivores functional group during the Competition period. Note the increased dominance of silver hake during 2010-2015.

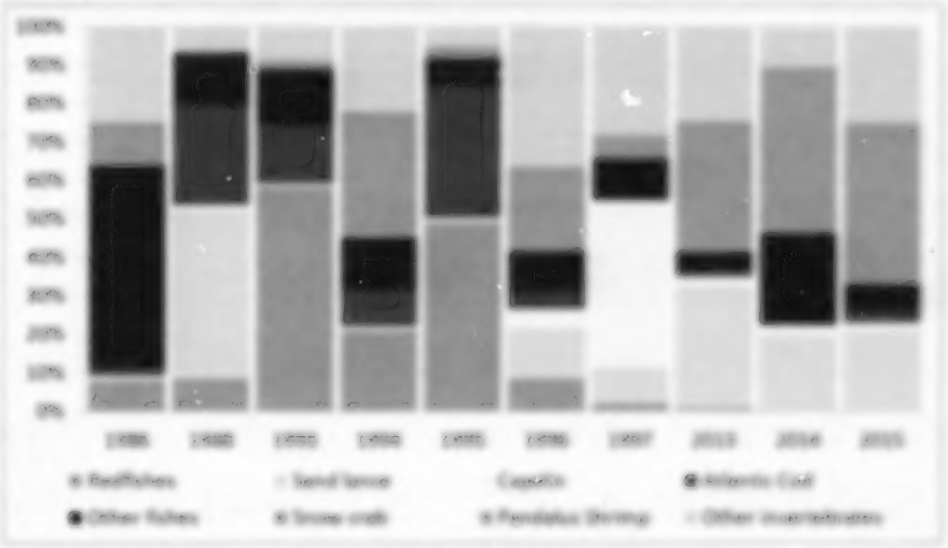


Figure 34. Diet composition of Atlantic Cod in NAFO Sub-Division 3Ps (% dry mass) from stomach contents collected during DFO 3Ps Spring surveys.

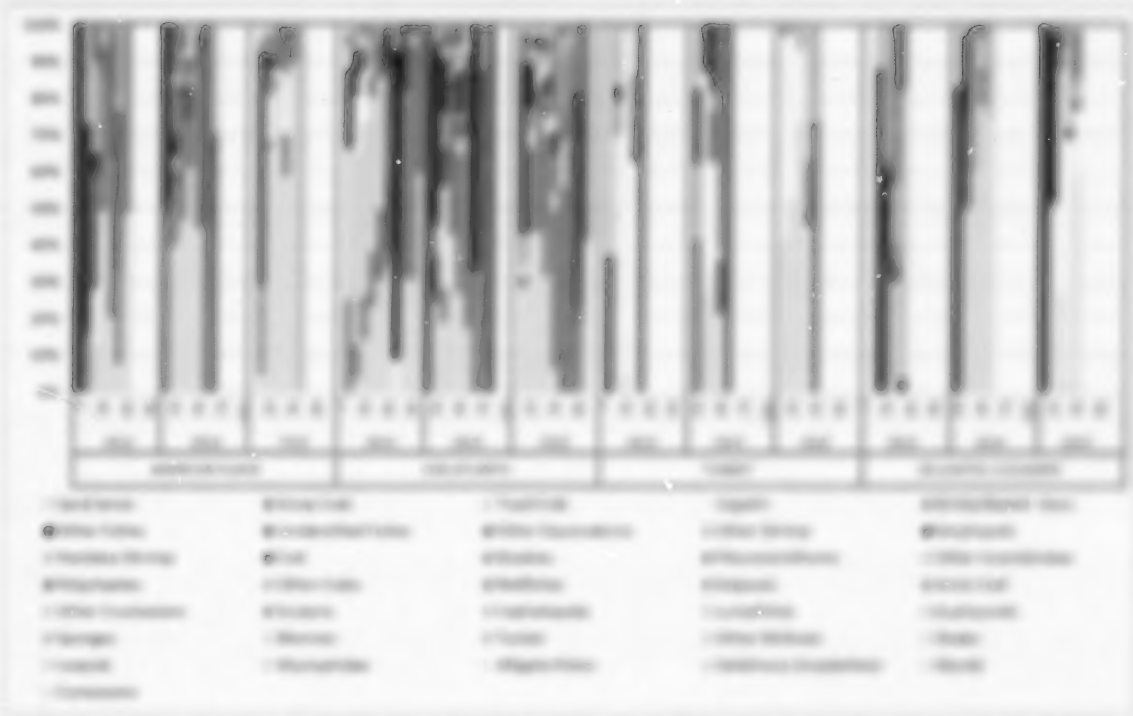


Figure 35. Comparison of Spring diet composition of key predators, by fish size (length in cm), in GSFD Subdivision 3Ps during 2013-15.